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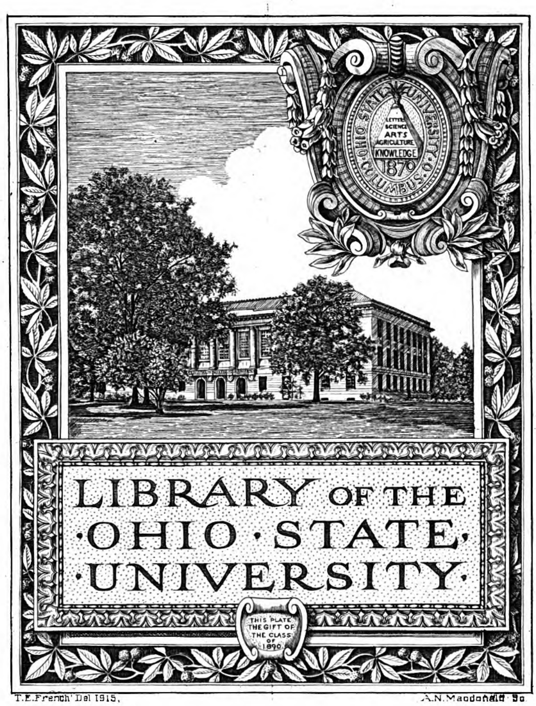

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# Seven Quickly Administered Tests of Physical Capacity

AND THEIR USE IN DETECTING PHYSICAL INCAPACITY FOR MOTOR ACTIVITY IN MEN AND BOYS

By ROYAL HUDDLESTON BURPEE, Ph.D.

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R. H. B.

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Seven Quickly Administered Tests of Physical Capacity

# INTRODUCTION

ACTIVE power to accomplish physical work and the ability to use this power constitute an individual's *physical capacity*. In any physical education program designed to foster continuous growth along socially acceptable lines, this capacity should be known before the individual participates in large-muscle activities.

The active power of the individual to accomplish physical work is important (1) because every individual has a crest load beyond which further exertion becomes a hazard, and (2) because numerous organic and functional defects may so reduce this tolerance for exercise that the slightest exertion is dangerous. As exertion becomes more strenuous the proportionate increase in the demands made upon the respiratory, cardiovascular, and other anatomical systems that are instrumental in maintaining the normal functioning of the body may be too great if defects are present. It is therefore necessary that defects which limit the individual's capacity be known if injury is to be prevented.

The detection of defects is negative and preventive, while education is positive and dynamic; hence, physical educators must also develop and sustain interest in worth-while activities. Since interest is sustained, not by repeated failure at unsuitable tasks, but by reasonable success following conscientious effort, it is obvious that physical education programs should be adapted to individual ability. This means that physical ability must be tested and programs properly adapted to this important factor.

Although it is true that knowledge of an individual's active power to accomplish physical work and his ability to use this power is not only desirable but necessary for wholesome participation, at the present time physical capacity of participants is not always determined. In numerous instances, especially in elementary and secondary schools, and in private institutions such as the Y. M. C. A., no attempt is made to ascertain physical fitness, and assignments to activity programs are made on either class or group

basis or left to individual caprice. The explanation usually given for this practice is that the technically trained staff, time, and equipment necessary for a comprehensive examination program are not available. Numerous solutions to this problem have been offered. Many quick and convenient tests have been devised, but with few exceptions they were arbitrarily developed by physicians before the modern methods of test construction were developed. As a result the values and limitations, the validity and reliability, of well-known and time-honored simple measures of physical capacity are still unknown.

The dearth of suitable methods of measuring physical capacity which do not require considerable time, knowledge, or equipment to administer motivated this study. An attempt has been made (1) to ascertain the methods of measuring physical capacity which can be administered with minimum equipment and time by an examiner not trained in medicine; (2) to divulge the significance and values of these measures; (3) to build these measures into a simple, quickly administered test requiring a minimum of equipment; and (4) to establish the values and limitations of the resulting test.

A test of this type cannot be substituted for a medical examination. Information secured from such a test, however, may be of sufficient importance to make it a valuable part of, or supplement to, the medical examination. It may also prove useful as a preliminary test to the medical examination by separating or screening individuals into two groups: (1) those who are in questionable physical condition and should be referred to a physician before participation in large-muscle activities; and (2) those who react to exercise in a normal way and presumably may engage in large-muscle activities pending a medical examination. It is possible that its speed, efficiency, and economy may enable administrators to inaugurate a testing program where it has heretofore been impossible.

# PART I

## NEED FOR, AND CONSTRUCTION OF, A TEST FOR MEASURING PHYSICAL CAPACITY

# CHAPTER I

## THE NEED FOR A FUNCTIONAL TEST OF PHYSICAL CAPACITY

MANY methods have been devised for measuring an individual's active power to accomplish physical work and his ability to use this power;[1] the most important of these methods is the complete medical examination.

The complete medical examination, the basic and standard measure of health, is not a single test but a battery of tests, observations, and measurements. In one form recommended for apparently healthy individuals[2] there are sixty-five items. In administering this examination, the physician selects from all available tests those which, in his opinion, constitute a survey of the important physiological and anatomical units of the body; each organ and each system is examined for the purpose of detecting abnormal or pathological conditions. The result—a series of measurements, observations, and impressions—forms the basis for the conclusion or diagnosis. This diagnosis usually consists of a statement of the presence or absence of disease, a list of the questionable areas which need further investigation, and perhaps an estimate of the subject's future health. As these conclusions are largely subjective, the patient's only safeguards are the knowledge, training, experience, and integrity of the examiner. Consequently, in New York and many other states the formulation of such diagnosis is the exclusive function of persons licensed to practice medicine.

[1] See discussion of these two factors on page 1.

[2] Although there is a difference of opinion among qualified workers as to the items that should be included in a complete medical examination, there is some agreement concerning what constitutes a desirable medical examination for apparently healthy people. The American Medical Association has considered this problem, and the items recommended for this purpose are given in a form entitled "A Periodic Health Examination." [2]

Although the complete medical examination, when administered by competent examiners, is the most valid method of detecting defects, it is not a comprehensive measure of physical capacity. Since all the measurements are made with the subject at rest, it does not reveal physical ability, an important aspect of capacity, and suitable functional tests of physical ability must be used to supplement it.

When physical capacity is measured by means of a complete medical examination and tests of physical ability, the procedure is an involved one, requiring considerable time, knowledge, and equipment. In most physical education programs it is not possible to administer these examinations to all pupils upon entrance, and tests must be scheduled over a considerable period of time. Pending these examinations, there is little or no basis for intelligent direction of students' physical activities, and in these situations a test is needed which will separate pupils into two groups: (1) those who are apparently normal and may be permitted to take part in supervised activities until examined by a physician; and (2) those in questionable physical condition who should be referred to a physician for diagnosis before engaging in physical activities. Such a test would be of value in guidance, as well as in numerous other fields, for though it is generally recognized that counsel should be based upon a knowledge of the subjects' physical condition, this information is not always available, limited facilities in many programs preventing the administration of the medical examination and supplementary physical ability tests.

A test identifying those subjects who are apparently normal and those in questionable physical condition should require a minimum of time, equipment, and knowledge, for it must be administered quickly, and at various places, by relatively unskilled school personnel. In addition, it is highly desirable that it measure important aspects of functional condition, so that information derived from its use may be used to supplement the static tests of the medical examination.

The voluminous literature on health which describes the many methods and devices proposed for the measurement of physical capacity was surveyed to find out whether there were any meth-

ods that could be administered quickly, without extensive equipment, by examiners not trained in medicine, which were suitable as supplementary-screening tests. This survey follows.

## Survey of Possible Methods

### THE SHORT MEDICAL EXAMINATION

Where limitations of staff and time have prohibited complete medical examinations, a substitute has been sought in a short examination. Although there are various opinions among individual examiners concerning what the content of this examination should be, the items frequently tested are the nose, throat, heart, lungs, skin, and male genitalia. This examination is usually administered to prevent the collapse of participants in activity programs and to guard against the spread of infectious diseases. When administered by skillful examiners, it may accomplish these purposes and thereby preclude unfavorable publicity and possible lawsuits. However, as a phase of an educational program, it is subject to the criticism that the results are largely negative, for if the examination does not disclose a defect, the individual is "negative" and is passed for participation in the activity program. Although this examination is a quick, efficient screening test, it requires a high degree of medical competence and gives little or no indication of physical ability.

### PHYSICAL EXAMINATIONS ADMINISTERED BY INDIVIDUALS NOT LICENSED IN MEDICINE

When licensed physicians have not been available, medical or physical examinations have been performed by members of the physical education staff or by individuals who had had some medical training. Such examinations have little or no legal status, and have been little used in tax-supported institutions such as the public schools. This is probably accounted for by the fact that when attendance is compulsory the possible liability for injuries due to misdirection and errors of judgment is greater than when attendance is voluntary. However, these examinations have been extensively employed in privately supported institutions, espe-

cially in the Young Men's Christian Association and its branches.

Physical examinations administered by individuals with irregular training have doubtful reliability and validity. Although it is possible for an individual without a medical degree, through study and experience, to become highly competent in this field, it is also possible for an inexperienced examiner grossly to misinterpret the facts. It is true that in the determination of physical condition there are areas in which the physical educator can function legitimately, but a physical examination administered by individuals not licensed in medicine is not a satisfactory substitute for a complete medical examination.[3]

### TESTS OF CARDIOVASCULAR CONDITION

Numerous techniques have been suggested for determining cardiovascular condition. Among those tried are the following: comparison of horizontal and vertical systolic blood pressure and heart rates [Crampton, 35];* comparison of horizontal and vertical heart rates [McCurdy, 72: 421-32]; heart rate reaction to exercise [Meylan, 81: 443-44]; normal heart rate, increase after exercise, reaction after exercise [Foster, 47]; systolic and diastolic blood pressure [Barach, 10]; reaction of systolic blood pressure to exercise [Barringer, 12]; horizontal and vertical pulse rates, systolic blood pressure, pulse rate reaction after exercise, pulse rate immediately after exercise [Schneider, 117]; sitting pulse rate, pulse rate reaction after exercise [Campbell, 27]; standing pulse rate, pulse rate reaction to exercise [Michigan Pulse Rate Test, 82]; pulse rate and blood pressure before, during, and after holding a column of mercury 40 mm. high in a U-tube by force of air breathed into one side of tube [Warner and Hambly, 140]; age, weight, standing pulse rate, standing systolic and diastolic pressures, sitting systolic and diastolic pressures, breath-

[3] In the determination of physical condition, the proper function of the physical educator who is not a physician is controversial. The subject, although an interesting one, is not within the scope of this study.

* Throughout this study, the sources of information are indicated by numbers in brackets designating the book or article in the Bibliography to which reference is made. This number may be followed by a colon and a figure which gives the specific page or pages referred to.

holding after exercise, and pulse rate after exercise [McCurdy and Larson, 76: 12-41]; comparison of pulse reactions after exercises of varying intensity [Sievers, 128]; flarimeter—various systolic pressures after standard forced expiration [Wells, 144: 44-48].

The status or condition of the cardiovascular system is an important factor in determining the amount of physical exertion that is desirable, for overexertion by individuals with defects in this area may result in death. In spite of extensive investigation, the validity of cardiovascular tests is still unsettled. Many of these tests were developed before statistical methods of test construction were known, and later researches have yielded conflicting evidence concerning their validity. The advocates of these tests [11] believe them to be valid diagnostic measures of cardiac condition, while other equally competent investigators [22] [147] find that they measure not true cardiac reserve but the influence of other, extra-cardiac, factors.

Several cardiovascular tests are quickly administered with a minimum of equipment and knowledge, and the information which they elicit is a valuable supplement to the medical examination. However, these tests are only partial measures, for cardiac defects, important as they are, are only one of many types of defects which may limit physical capacity. The limited areas they measure and their uncertain validity render cardiovascular tests unsuitable for supplementary-screening purposes.

## THE FLARIMETER TEST AND THE ORGANIC EFFICIENCY TEST

The Flarimeter Test (circulatory fitness as measured by changes in blood pressure produced by increase in intrathoracic pressure) and the Organic Efficiency Test are highly developed supplementary tests. The Flarimeter Test was developed for the use of insurance medical examiners, and the indications are that it is a valuable test for this purpose. "The time schedule for the standard technique should take less than seventeen minutes, which means skill if the examiner is to observe and record twenty-eight different readings accurately." [144: 47] The Organic Efficiency

Test is intended for specialists in health and physical education and for physicians. The time required for its administration is not over ten minutes, and a double action stop watch, regulation stairs, sphygmomanometer, stethoscope, and Flarimeter are required. [76: 17] The time, knowledge, and equipment required for the administration of these tests render them unsatisfactory for use in the present investigation.

### COMPOSITE TESTS

Tests composed of a battery of items have also been used to measure physical capacity. The composition of several of these batteries is as follows: Body weight in relation to age and height, breath-holding, pulse rate return after exercise, half-mile run, potato race, health inspection [Stolz, 134]; serious ailments, physiological efficiency, physical development, physical ability, mental qualities [Rapeer, 103]; miscellaneous stunts, such as walking in a straight line, high kick, and frog stand [Brace, 19: 105]; Physical Fitness Index—lung capacity, grip, back strength, leg strength, arm strength divided by the norm for individual's age and weight [Rogers, 109]; General Motor Achievement Quotient—track and field events, pull-up strength [McCloy, 71: 46-61]; Physical Efficiency Test for Freshman College Women, medical test, anthropometric test, motor ability test [Wayman, 142]; dip (parallel bars), baseball throw, football punt, standing broad jump, quarter mile run, long dive, dodging [Cozens, 34].

Composite tests may be divided, according to their functions, into two groups: (1) screening tests similar to that reported by Stolz; and (2) supplementary tests similar to those developed by Rapeer, Brace, McCloy, and Rogers.[4] The screening tests have not been validated and their values are unknown. The tests constructed by Rogers, McCloy, and Cozens have been validated, but

[4] The emphasis that Rogers has placed upon the use of the physical capacity test as an indication of physical fitness may cause the reader to question why this test has been classified as a supplementary test. In this connection, it should be remembered that Rogers emphatically states, "Medical examination should precede physical capacity tests, and medical examiners should certify to pupils' fitness to undergo tests. Pupils subject to hernia, with any cardiac defects or recovering from recent illness or operations should be barred from all lifting tests." [108]

they are not suitable for use before the medical examination as the items used require considerable exertion—too much to be safe for unselected groups. These tests also require considerable time to administer as individual tests. By means of carefully planned group and chain examination procedures,[5] administration time may be materially reduced. This requires, however, that a large number of examiners[6] and subjects be present at a given place at a specified time—an arrangement difficult to accomplish in the Y. M. C. A. and other organizations where participants enroll continuously throughout the year. In these situations, the length of time required for administration prohibits the use of these tests.

The Brace Test was designed to measure native motor abilities and not cardiovascular or organic condition, and the items, a series of stunts, do not measure this condition. The results of this test furnish valuable specific data which are a useful supplement to the medical examination. The test was not intended to be, and is not, suitable for the identification of individuals in questionable physical condition.

## Summary

The optimum amount of physical activity that should be engaged in is conditioned by the organic power of the individual and his ability to use this power, that is, his physical capacity.

Numerous methods have been proposed for the measurement of this capacity. The complete medical examination is a valid test for detecting the presence of defects which may limit organic power, and when supplemented by tests measuring the ability to use this power it is a valid measure of physical capacity. Difficulty in administering these examinations has, in many instances, made it impractical to examine all pupils before activity classes begin and also to determine physical condition as a basis for guidance. In these and numerous similar situations where physical

[5] An examination station is set up for each test item with an individual examiner. A group of from 20 to 40 is examined at one time. Each subject passes from one station to another. [107: 173-85]

[6] Rogers recommended seventeen examiners. [107: 176]

capacity is a determining or limiting factor, a quick, easily-administered test is needed to preface the complete medical examination which will identify (1) individuals who are apparently healthy and may reasonably be expected to carry normal activity loads, and (2) individuals who are in questionable physical condition. It is desirable that a preliminary test of this type measure aspects of physical condition not measured by the medical examination, so that its results may supplement, rather than duplicate, the medical examination. Functional tests would be satisfactory for this purpose, as the medical examination is largely a static measure.

A survey of the methods available for the measurement of physical capacity revealed that there were no valid measures suitable for screening individuals before a medical examination and for supplementing the medical examination which did not require either considerable time, equipment, or knowledge to administer as individual tests.

# CHAPTER II

## SELECTION OF TEST ITEMS

This survey of the available methods suitable for screening individuals before a medical examination and for supplementing the medical examination showed that while there were none which did not require considerable time, equipment, or knowledge to administer there were individual items, offering promise, which might be used in developing a supplementary-screening test of the type desired. This discovery led to an analysis of the techniques or items used in physical education tests to determine those which were suitable for the purpose of this study, namely, the development of a supplementary-screening test which would require a minimum of time, knowledge, and equipment to administer. These requirements greatly limited the number of items that might be used, and the problem was not that of selecting the most valid of numerous available items, but the identification and development of a sufficient number thereof.

### Method Used

An impartial survey of the literature concerning physical education tests was made, but beyond the rejection of obviously unsuitable material, no selection was attempted. Tests were added until further addition would have duplicated the items already obtained from previously studied tests.

Each item was analyzed to determine the conditions necessary for administering it. Items which required a minimum of time, equipment, and knowledge to administer were retained for further study; other items were rejected. For the purpose of this analysis, minimum time was defined as not more than two minutes for an individual test; minimum equipment, as a small unobstructed area, and such equipment as is usually available or readily obtain-

able (watch, tape measure, etc.); minimum knowledge, as the ability to follow instructions for the administration of a test which does not require medical diagnosis.

In this study, eighty-nine tests were analyzed. A list of their sources is given below. For convenience in recording data, the techniques used in each test are designated by means of numbers. The numbers are those used in Table 1 for each technique or item.

*Items or Techniques Used in Tests of Health and Physical Education*

American Physical Education Association Motor Ability Tests [3]
11 (standing), 11 (moving), 216 (40 yards), 49, 25, 154, 216 (60 yards), 125, 48, 14 (running), 132 (running), 20 (12 inch ball, 20 feet, accuracy), 196, 193, 155, 216 (100 yards), 238, 221, 290, 191 (for distance), 16 (30 feet, for accuracy).

Baldwin, B. T. [6]
303, 122, 58.

Baltimore Public Athletic League Standards (Author not given) [7]
63, 49, 219, 220.

Baltimore Public Athletic League Test for Girls (Author not given) [8]
12, 162, 25.

Bancroft, J. H. [9]
192.

Barach, J. H. [10]
37 (systolic), 201, 37 (diastolic).

Barringer, T. B., Jr. [12]
40.

Bliss, James G. [16]
218, 63, 295, 148, 206, 49, 95, 118, 21 (speed pass), 26, 25, 17.

Brace, D. K. [19]
302, 149, 241, 157, 75 (from front leaning rest), 251, 150, 149 (feet together twice), 33, 129, 151, 158, 253, 254, 150 (full turn), 157 jump to feet), 69, 256, 265, 255.

Brace, D. K. [20]
21 (rapid pass), 22, 23 (position), 23 (for goal), 24, 26.

Brace, D. K. [18]
17, 17 (underhand), 17 (overhand infield throw), 32 (indoor ball), 19 (rapidly).

Brownell, C. L. [24]
192 (silhouettes).

Burpee, R. H. [25]
201, 203, 199, 172, 187, 111.

California Decathlon Test (Author not given) [26]
293, 63, 75, 241, 118, 213, 193, 125, 49, 48, 216, 29, 25, 17, 244, 268 (20 yards), 148, 216 (40 yards), 219, 31 or 299, 289, 29, 24, 25, 17, 128, 244, 28, 148, 219, 193.

Campbell, J. M. [27]
202 (5 minutes), 199 (after performing 144).

Collins, V. D. and Howe, Eugene C. [29]
226, 169.

Collins, V. D. and Howe, Eugene C. [30]
72, 73, 268, 218, 49, 95, 213 (height), 20, 192, 89, 200, 56, 201, 37, 55, 143, 291, 11, 68, 123, 298, 261, 262, 263.

Cozens, F. W. [34]
75, 16, 107, 49, 222, 83, 87.

Crampton, C. Ward [35]
55, 56.

Davenport, C. B. [38]
303, 122.

De Busk, B. W. [39]
297, 303.

Delaplaine, Roy W. [41]
184, 3 (high bar), 213, 136, 165, 3 (rings), 218, 220, 48, 49, 125, 237.

Detroit Physical Education Department Boy's Decathlon Record (Author not given) [42]
63, 49, 27, 220, 241, 48, 125, 132 (standing), 132 (running), 237, 75.

Dunfermline Scale (Author not given) [43]
174, 175, 176, 177.

Foster, W. L. [47]
201, 141, 74.

Freiberg, Albert [48]
194.

Galton, F. [49]
46, 259, 208, 90, 120, 66.

Garfiel, Evelyn [50]
287 (three holes arranged in form of a triangle).

Geer, W. H. [52]
192 (silhouettes).

Gross, Howard [56]
274 (40 yards), 273 (40 yards), 272 (20 yards), 77, 78.

Highsmith, J. A. and Sorenson, D. [60]
1, 186, 235, 122.

Kleeberger, Frank L. [63]
220, 48, 95, 230, 92, 268 (speed), 268 (strokes), 268 (distance), 77, 163, 43, 306, 94, 145, 248.

Lovett, R. W. [65]
232.

Martin, E. G. [69]
261, 262, 263.

McCloy, C. H. [71: 46-61]
216 (50–100 yards), 48 or 49, 125, 237, 63, 25.

McCloy, C. H. [71: 46-61]
1, 30, 3, 122, 154, Brace Test, 111.

McCurdy, J. H. [73]
14, 48, 125, 220.

McCurdy, J. H. [72]
55.

McCurdy, J. H. [74: 317]
8, 160, 162.

McCurdy, J. H. [74: 319]
64, 64 (15 seconds), 64 (eyes closed), 210, 210 (one foot 15 inches from floor, eyes closed), 210 (heel raised from floor, eyes open), 210 (heel raised from floor, eyes closed), 209.

McCurdy, J. H. and Larson, B. A. [76: 11-41]
1, 303, 226, 109, 45, 201, 38 (systolic and diastolic), 37 (systolic and diastolic), 203.

McKenzie, R. Tait [78]
233.

Metcalf, T. N. [80]
48, 96, 222, 20, 125, 14, 63, 220, 224, 125, 48, 26, 63 or 214, 216 (with burden), 83, 268 (25 yards), 275, 284, 20.

Meylan, G. L. [81: 442]
170, 125, 152, 273 (150 feet), 272 (75 feet), 277 (75 feet), 85, 140, 110, 249, 54, one of (216, 290, 239, 268, 166).

Meylan, G. L. [81: 443]
181, 65, 4, 200, 201, 36, 37, 203.

Michigan Test (Author not given) [82]
201, 228, 291.

Miles, W. R. [83]
52.

Miles, W. R. [84]
8.

Manny, F. A. [68]
174, 175, 178, 179, 180.

Mosso's Test (Other data not given) [86]
260.

New York State Physical Ability Test (Author not given) [89]
220, 49, 63, 218, 227, 20.

Nichols, J. H. [90]
213, 125, 216 (118 yards), 14.

Oppenheimer's Scale [91]
6, 57 (full expiration).

Outdoor Athletic Tests for Boys (Reported by J. R. Brown) [23]
218, 48, 49, 216 (25 yards), 16, 125, 220, 237.

Pignet's Formula (Other data not given) [97]
303, 57, 122.

Playground and Recreation Association Athletic Badge Test for Boys (Author not given) [99]
63, 213, 49, 219, 218, 24, 25, 48, 219, 220, 17, 16, 125, 221, 237.

Playground and Recreation Association Athletic Badge Test for Girls (Author not given) [100]
10, 193, 5, 218, 25, 17 (12 inch ball), 299, 289, 29, 19 (12 inch ball), 11, 227.

Playground Athletic League, Baltimore, Maryland, Swimming Test [101]
86, 268 (free style, 20 minutes), 77 (any 4 A. A. U. dives), 272, 274 (50 yards), 268 (220 yards, free style), 272 (25 yards in 30 seconds), 294 (1 minute), 51 (50 feet, tired swimmer's carry, or cross chest carry), 280 (1st 25 by 272, 2nd 25 by 273, 3rd 25 by 269, 4th 25 by 274), 231 (demonstrate for 3 minutes for rhythm).

Ponderal Index (Other data not given) [102]
303, 122.

Rapeer, W. L. [103]
119, 201, 203, 229, 199, 303, 122, 58, 218, 219, 216 (75 yards), 220, 49, 48, 290, 132 (running), 22, 25, 20, 172.

Reed, W. T. [104]
106, 104, 103 (accuracy), 26 (baskets per minute), 218, 220, 223, 49, 48, 125, 14, 191, 237, 16, 17, 63, 75, 213 (16 feet), 262 (left and right), 11 (headstand on balance beam), 192, 3, 146, 1, 122, 303, 168, 154, 11 (squat on toes, time).

Reilly, Frederick J. [105]
192, 139, 193 or 216 (50 and 80 yards), 262, 60, 25, 17, 26, 289, 114, 113.

Reilly, Frederick J. [105]
192, 200, 290, 193 or 216 (40 yards), 134, 49, 125, 63, 262, 236, 67, 295, 60, 17, 29 (80 yards).

Richards, J. H. [106]
63, 49, 48, 132 (standing), 132 (running), 125, 218.

Rogers, F. R. [110]
58, 262 (right), 259 (back and legs), 207 (on stall bar bench), 197 (rings 12 to 16 inches in diameter, under edge four feet from floor), 168.

Rogers, F. R. [109]
262, 63, 75, 303, 122, 58, 9, 161.

Sargent, D. A. [114]
303, 154, 122.

Sargent, D. A. [115]
88, 197, 206, 34, 211, 70.

Sargent, D. A. [113]
258, 258 (back and legs), 262, 58, 75, 63, 168.

Schneider, E. C. [117]
200, 56, 201, 37, 55, 143, 291.

Schwegler, R. A. and Engelhardt, J. L. [125]
154.

Sheffield, Lyba and Nita [127]
279, 280, 97, 98, 99, 282 (20 yards), 283, 204, 204 (crawl kick), 205, 234 (20 yards), 277 (20 yards), 78, 277 (25 yards), 278 (25 yards), 278 (50 yards), 270 (50 yards), 274 (50 yards), 271 (50 yards), 189

(35 yards), 281, 269, 268 (racing turn), 77 (running swan), 77 (back dive), 98 (motionless), 294 (one minute), 79, 80, 147, 267, 81, 44 (wrist, front neck, body, rear neck), 51 (head, underarm, side chest, side head, cramp), 190, 231.

Sigma Delta Psi Test (Author not given) [129]
220, 137, 125, 48, 239, 191, 20, 107, 268, 225, 296, 192.

Stecher, W. A. [131]
49, 22, 216 (30 yards), 216 (40 yards), 218, 63, 156, 25, 216 (75 yards), 220, 275 (220 yards), 48, 213, 125, 16 (75 yards).

Stecher, W. A. [132]
218, 219, 216 (75 yards), 220, 49, 48, 290, 132 (running), 22, 25, 125, 16 (indoor).

Stolz, H. R. [134]
124, 45, 201, 121, 203, 223, 193, 4.

Stolz, H. R. [134]
124, 45, 199, 193, 47, 93, 4.

Steet's Formula (Other data not given) [133]
303, 122.

University of Oregon Test (Author not given) [137]
125, 14, 213, 216, 268 (100 yards).

Warner, E. C. and Hambly, W. D. [140]
130.

Wayman, Agnes R. [142]
192, 213, 162, 285, 125, 252, 43, 29, 70, 195, 25, 17, 227, 247, 91, 159, 132, 264, 293, 30, 26, 240, 138.

Wayman, Agnes R. [141]
171, 58, 168, 57, 262, 125, 217, 213, 50, 41, 296, 115.

Wells, P. V. [144: 44-48]
109.

Whipple, G. M. [145: 151-53]
292.

Whipple, G. M. [145: 130-47]
287.

Whipple, G. M. [145: 148]
131.

Wood, T. D. [149]
242.

TABLE 1

ITEMS USED IN TESTS OF PHYSICAL EDUCATION CLASSIFIED ACCORDING TO EASE OF ADMINISTRATION

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge* | Administration Requiring More Than Minimum of | | |
|---|---|---|---|---|---|
| | | | Time | Equipment | Knowledge |
| 1 | Age | x | | | |
| 2 | Ailments, serious | | x | x | x |
| 3 | Apparatus work | | | x | |
| 4 | Appearance, general | x | | | |
| 5 | All-up Indian Club Race | | | x | |
| 6 | Arms, girth upper | x | | | |
| 7 | Arms out at the side, horizontal position, well back. The person then leans backward, supported by two other pupils with support at the wrist | x | | | |
| 8 | Atoxiameter | | | x | |
| 9 | Back lift | | | x | |
| 10 | Balancing, one deep-knee bend | x | | | |
| 11 | Balance | x | | | |
| 12 | Balancing, on a beam | | | x | |
| 13 | Bar snap for distance | | | x | |
| 14 | Bar vault | | | x | |
| 15 | Baseball | | | x | |
| 16 | Baseball, throw for distance | | | x | |
| 17 | Baseball, pitching | | | x | |
| 18 | Baseball, situations | | | x | |
| 19 | Baseball, throw and catch | | | x | |
| 20 | Baseball, throwing | | | x | |
| 21 | Basketball | | | x | |
| 22 | Basketball, overhead throw | | | x | |
| 23 | Basketball, dribble | | | x | |
| 24 | Basketball, throw for accuracy | | | x | |
| 25 | Basketball, throw for distance | | | x | |
| 26 | Basketball, goal shooting | | | x | |
| 27 | Basketball, overhead shot | | | x | |
| 28 | Basketball, pass for accuracy | | | x | |
| 29 | Basketball, throw for goal | | | x | |
| 30 | Basketball race | | | x | |
| 31 | Bat-ball | | | x | |
| 32 | Batting | | | x | |
| 33 | Bend and touch one knee to floor, and stand up while grasping other foot behind the body | x | | | |

* Minimum Time—Two minutes or less for an individual test. Minimum Equipment—A weight scale, small unobstructed area, other readily obtainable instruments, such as tape measure, stop watch, etc. Minimum Knowledge—Ability to follow instructions for test administration not requiring medical diagnosis.

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 34 | Bend forward, touching the fingers to the floor | x | | | |
| 35 | Bicycling | | | x | |
| 36 | Blood pressure, horizontal | | | x | x |
| 37 | Blood pressure, vertical | | | x | x |
| 38 | Blood pressure, sitting | | | x | x |
| 39 | Blood pressure, diastolic | | | x | x |
| 40 | Blood pressure, after raising ten-pound dumbbells from level of shoulders to full extension of arms, then swinging down between spread legs | | | x | x |
| 41 | Boom | | | x | |
| 42 | Boom, forward circle on | | | x | |
| 43 | Boxing | | | x | |
| 44 | Breaks in lifesaving | | | x | |
| 45 | Breath-holding | x | | | |
| 46 | Breathing capacity | | | x | |
| 47 | Breathlessness after activity | x | | | |
| 48 | Broad jump, running | | | x | |
| 49 | Broad jump, standing | | | x | |
| 50 | Buck | | | x | |
| 51 | Carry methods in lifesaving | | | x | |
| 52 | Catching water which is being discharged by a pendulum | | | x | |
| 53 | Catching football | | | x | |
| 54 | Championship, win college championship in an individual event | | x | x | |
| 55 | Change in pulse rate from horizontal to erect position | x | | | |
| 56 | Change in systolic blood pressure from horizontal to erect position | | | x | x |
| 57 | Chest, ninth-rib measurement | x | | | |
| 58 | Chest, capacity | | | x | |
| 59 | Chest, depth | x | | | |
| 60 | Chest, expansion | x | | | |
| 61 | Chest, girth in expansion | x | | | |
| 62 | Chest, width | x | | | |
| 63 | Chinning | x | | | |
| 64 | Close-walk-stand position | x | | | |
| 65 | Color of the skin | x | | | |
| 66 | Color sense | x | | | |
| 67 | Combination dip | | | x | |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 68 | Coordination | x | | | |
| 69 | Cross feet, sit down cross-legged, get up (use of arms not allowed) | x | | | |
| 70 | Deep-knee bend | x | | | |
| 71 | Defense | | | x | |
| 72 | Defects not likely to entail immediate limitation of vigorous exercise | | x | x | x |
| 73 | Defects which restrict subject's muscular exercise | | x | x | x |
| 74 | Difference in pulse rate before exercise and after forty-five seconds of rest | x | | | |
| 75 | Dipping | | | x | |
| 76 | Discus throw | | | x | |
| 77 | Diving, fancy | | | x | |
| 78 | Diving, water | | | x | |
| 79 | Dive or jump from a five- or ten-foot platform, swim twenty-five yards, side stroke, upper arm held in carry position | | | x | |
| 80 | Dive, shallow, and swim twenty-five yards, on the back, arms held in carry position | | | x | |
| 81 | Dive, shallow, and swim under water from ten to thirty feet | | | x | |
| 82 | Dive, swim ten yards for form | | | x | |
| 83 | Dive, and roll for distance on mat | | | x | |
| 84 | Dive, on mats | | | x | |
| 85 | Dive, six-foot (water) | | | x | |
| 86 | Dive, surface, in at least eight feet of water, and bring up object | | | x | |
| 87 | Dodging | | | x | |
| 88 | Elbows to knees from a supine position | x | | | |
| 89 | Endurance | x | | | |
| 90 | Eyesight | x | | | |
| 91 | Fall, hanging on boom | | | x | |
| 92 | Falling | x | | | |
| 93 | Fatigue after activity | x | | | |
| 94 | Fencing | | | x | |
| 95 | Fence vault | | | x | |
| 96 | Fence, climbing eight-foot (time required) | | | x | |



TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 97 | Floating, true (in water)............ | | | x | |
| 98 | Floating, face submerged............ | | | x | |
| 99 | Floating, advanced positions.......... | | | x | |
| 100 | Flying rings....................... | | | x | |
| 101 | Flying rings, backcut off............ | | | x | |
| 102 | Football.......................... | | x | x | |
| 103 | Football, drop kick for goal.......... | | | x | |
| 104 | Football, pass for distance............ | | | x | |
| 105 | Football, pass for accuracy........... | | | x | |
| 106 | Football, punting for distance......... | | | x | |
| 107 | Football, punting.................... | | | x | |
| 108 | Forearms, strength, with dynamometer | | | x | |
| 109 | Flarimeter......................... | | x | x | x |
| 110 | Front rest, get up to front rest on high horizontal bar three different ways..... | | x | x | |
| 111 | Front leaning rest, from standing position............................ | x | | | |
| 112 | Games............................ | | x | x | |
| 113 | Golf, driving in.................... | | | x | |
| 114 | Golf, putting....................... | | | x | |
| 115 | Gymnastic lesson, short............. | | | x | |
| 116 | Handspring....................... | x | | | |
| 117 | Handstand........................ | x | | | |
| 118 | Half lever......................... | | | x | |
| 119 | Health Scale, twenty-five points (total); count off four points for each serious ailment or defect during the school year; add the four points when remedied or corrected. For uncleanliness reported, count off one point, and do not add one when corrected..................... | | x | x | x |
| 120 | Hearing.......................... | x | | | |
| 121 | Heart rate after twenty-five forward body bends in twenty-five seconds..... | x | | | |
| 122 | Height........................... | x | | | |
| 123 | Height-weight relationship........... | x | | | |
| 124 | Height-weight-age relationships....... | x | | | |
| 125 | High jump, running................. | | | x | |
| 126 | High jump, standing................ | | | x | |
| 127 | Hockey........................... | | | x | |
| 128 | Hockey, goal shot.................. | | | x | |



TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of: Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 129 | Hold toe of each foot in opposite hand, jump up, and jump free foot over the held foot | x | | | |
| 130 | Holding up a column of mercury 40 mm. high in a "U" tube by force of breath blown into one side of the tube | | | x | |
| 131 | Holding needle in holes of different size | x | | | |
| 132 | Hop, step, and jump | | | x | |
| 133 | Hop on toes of each foot | x | | | |
| 134 | Hop, step, and leap | | | x | |
| 135 | Hopping one hundred feet | x | | | |
| 136 | Horse, side | | | x | |
| 137 | Hurdles, low twenty-yard | | | x | |
| 138 | Hurdle race | | | x | |
| 139 | Hygiene | | x | | |
| 140 | Hygiene, written examination | | x | | |
| 141 | Increase in heart rate after running in place at rate of 180 steps per minute for thirty seconds | x | | | |
| 142 | Increase in heart rate after hopping one hundred feet | x | | | |
| 143 | Increase in heart rate after raising body five times in fifteen seconds by placing right foot on chair eighteen inches high | x | | | |
| 144 | Increase in pulse rate after mounting a block thirteen inches high twenty-eight times per minute for three minutes | | x | | |
| 145 | Initiative | x | | | |
| 146 | Intelligence | | x | | |
| 147 | Jump in water dressed, undress, and continue swimming fifty yards | | | x | |
| 148 | Jump and reach | x | | | |
| 149 | Jump into air and clap feet together | x | | | |
| 150 | Jump into air and make a half turn | x | | | |
| 151 | Jump into air and slap both heels with hands behind back | x | | | |
| 152 | Jumping over a horizontal rope twenty inches high | x | | | |
| 153 | Jumping over a side horse | | | x | |
| 154 | Jumping, vertical height | x | | | |
| 155 | Kick for height | x | | | |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of: Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 156 | Knee raising | x | | | |
| 157 | Kneel on both knees (arms folded behind back), get up | x | | | |
| 158 | Kick right foot so that toes come level with shoulders | x | | | |
| 159 | Ladder climbing | | | x | |
| 160 | Leaning backward, in either standing or sitting position | x | | | |
| 161 | Leg lift | | | x | |
| 162 | Leg raising | x | | | |
| 163 | Life-saving | | | x | |
| 164 | Lifting weights | | | x | |
| 165 | Mats | | | x | |
| 166 | Lifesaving methods, tests | | x | x | |
| 167 | Long horse, straddle vault | | | x | |
| 168 | Lung, capacity | | | x | |
| 169 | Lunge with a foil for accuracy | x | | | |
| 170 | Marching and calisthenics with emphasis on posture | | x | | |
| 171 | Medical test, height, weight, hemoglobin, heart, lungs, eyes, teeth, nose, throat, skin, hair, menstruation, bowels, posture, feet | | x | x | x |
| 172 | Mental qualities | | x | | |
| 173 | Mounting a block 13 inches high, 28 times per minute, for 3 minutes | | x | | |
| 174 | Nutrition of a healthy child of good social standing | | | | x |
| 175 | Nutrition, good, just short of excellent | | | | x |
| 176 | Nutrition, requiring supervision, on the border line of serious impairment | | | | x |
| 177 | Nutrition, seriously impaired and requiring medical treatment | | | | x |
| 178 | Nutrition, defective but can be cared for under present home and school conditions | | | | x |
| 179 | Nutrition, defective and requiring some degree of segregation for observation and control such as could be accomplished in a well-organized open air or other special classrooms | | | | x |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 180 | Nutrition, defective and requiring complete control as can best be in an institution especially equipped for that purpose | | | | x |
| 181 | Nutrition | | | | x |
| 182 | Overhead throw using eight-pound shot | | | x | |
| 183 | Pantograph | | | x | |
| 184 | Parallel bars | | | x | |
| 185 | Parallel bars, front vault right | | | x | |
| 186 | Pelvic breadth | x | | | |
| 187 | Physical ability | x | | | |
| 188 | Physical development (track and field events) | | x | x | |
| 189 | Plunge for distance | | | x | |
| 190 | Place victim's body over edge of pool or bank preparatory to resuscitation | | | x | |
| 191 | Pole vault | | | x | |
| 192 | Posture | x | | | |
| 193 | Potato race | | | x | |
| 194 | Pressure with thumb over sustentaculum tali | x | | | |
| 195 | Prone falling | x | | | |
| 196 | Pull-up kick on high bar | | | x | |
| 197 | Pulling up part of the weight of the body | x | | | |
| 198 | Pull up to front rest on high bar | | | x | |
| 199 | Pulse beats for two minutes following exercise | x | | | |
| 200 | Pulse rate, horizontal | x | | | |
| 201 | Pulse rate, vertical | x | | | |
| 202 | Pulse rate, sitting | x | | | |
| 203 | Pulse rate, after exercise | x | | | |
| 204 | Push-off, face submerged | | | x | |
| 205 | Push-off, side (swimming) | | | x | |
| 206 | Push up part of the weight of the body | x | | | |
| 207 | Push up from front leaning rest | x | | | |
| 208 | Quickness to respond to a signal by the eyes and ears | x | | | |
| 209 | Raise right foot from floor to side twelve inches, jump sideways to right, hitting left heel against right heel while in the air | x | | | |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of | | |
|---|---|---|---|---|---|
| | | | Time | Equipment | Knowledge |
| 210 | Raise right or left foot from the floor.. | x | | | |
| 211 | Rising on toes...................... | x | | | |
| 212 | Raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high........................ | x | | | |
| 213 | Rope climbing...................... | | | x | |
| 214 | Rope climbing, climb one rope twenty-four feet, pass to second rope, then to third, and descend the third.......... | | | x | |
| 215 | Rowing........................... | | | x | |
| 216 | Run.............................. | x | | | |
| 217 | Run, twenty-five yards............... | | | x | |
| 218 | Run, fifty yards..................... | | | x | |
| 219 | Run, sixty yards.................... | | | x | |
| 220 | Run, 100 yards...................... | | | x | |
| 221 | Run, 220 yards...................... | | | x | |
| 222 | Run, 440 yards...................... | | | x | |
| 223 | Run, one-half mile.................. | | | x | |
| 224 | Run, one mile....................... | | | x | |
| 225 | Run, two miles...................... | | | x | |
| 226 | Run, five times up and down a flight of twelve steps........................ | | | x | |
| 227 | Running and catching................ | | | x | |
| 228 | Running in place for fifteen seconds.... | x | | | |
| 229 | Running in place for thirty seconds, 180 steps per minute.................... | x | | | |
| 230 | Scaling............................ | | | x | |
| 231 | Schafer method of resuscitation....... | | x | | |
| 232 | Schulthes instrument................ | | | x | |
| 233 | Scoliosiometry...................... | | | x | |
| 234 | Sheffield sculling stroke.............. | | | x | |
| 235 | Shoulder breadth.................... | x | | | |
| 236 | Shot put, six-pound medicine ball..... | | | x | |
| 237 | Shot put, eight pounds............... | | | x | |
| 238 | Shot put, twelve pounds.............. | | | x | |
| 239 | Shot put, sixteen pounds............. | | | x | |
| 240 | Side fall position, raise leg........... | x | | | |
| 241 | Sit up............................ | x | | | |
| 242 | Snellen Test Chart (vision)........... | x | | | |
| 243 | Soccer............................ | | | x | |
| 244 | Soccer, kick for distance.............. | | | x | |
| 245 | Soccer, dribble..................... | | | x | |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of | | |
|---|---|---|---|---|---|
| | | | Time | Equipment | Knowledge |
| 246 | Soccer, goal kick.................... | | | x | |
| 247 | Somersaults......................... | x | | | |
| 248 | Sportsmanship...................... | x | | | |
| 249 | Squad, earn permanent place on a varsity squad......................... | | x | | |
| 250 | Spear throwing...................... | | | x | |
| 251 | Squat on heels with feet together, jump to straddle stand on heels............ | x | | | |
| 252 | Stall bars, top-up on................. | | | x | |
| 253 | Stand on left foot, bend forward and place hands on the floor, raise right leg and stretch it back, touch head to floor | x | | | |
| 254 | Stand with both feet tight together, bend down, extend both arms between the knees around the ankles, hold the fingers together in front of ankles............ | x | | | |
| 255 | Stand on left foot, right foot extended, sit down on heel of left foot without touching right foot or hand to floor, stand up.......................... | x | | | |
| 256 | Stand on left foot, right foot against inside of left knee, shut eyes, hold position | x | | | |
| 257 | Straddle vault for distance............ | | | x | |
| 258 | Strength of legs, dynamometer........ | | | x | |
| 259 | Strength, pull up.................... | x | | | |
| 260 | Strength and number of contractions of index finger......................... | | | x | |
| 261 | Strength of pectorals, dynamometer.... | | | x | |
| 262 | Strength of forearm flexors........... | | | x | |
| 263 | Strength of high abductors, by dynamometer.......................... | | | x | |
| 264 | Stunts............................ | x | | | |
| 265 | Supporting body on hands, knees against elbows........................... | x | | | |
| 266 | Swaying of body while attempting to stand motionless.................... | x | | | |
| 267 | Swim twenty-five yards; execute surface dive in deep water, and bring up object, continue swimming with object on hip ten yards.......................... | | | x | |
| 268 | Swimming......................... | | | x | |
| 269 | Swimming, side stroke single arm...... | | | x | |
| 270 | Swimming, trudgeon crawl............ | | | x | |

TABLE 1 (*Continued*)

| Item No. | Test Item | Administration Requiring Minimum of Time, Equipment, and Knowledge | Administration Requiring More Than Minimum of Time | Equipment | Knowledge |
|---|---|---|---|---|---|
| 271 | Swimming, alternate racing stroke | | | x | |
| 272 | Swimming, backstroke | | | x | |
| 273 | Swimming, breast stroke | | | x | |
| 274 | Swimming, crawl | | | x | |
| 275 | Swimming, distance | | | x | |
| 276 | Swimming, speed | | | x | |
| 277 | Swimming, side stroke | | | x | |
| 278 | Swimming, trudgeon | | | x | |
| 279 | Swimming, breathing in | | | x | |
| 280 | Swimming, change body position, back, side, and face | | | x | |
| 281 | Swimming, elementary backstroke | | | x | |
| 282 | Swimming, preliminary crawl | | | x | |
| 283 | Swimming, push-off back | | | x | |
| 284 | Swimming, under water | | | x | |
| 285 | Swinging jump | | | x | |
| 286 | Swinging jump, using vertical ropes and bar | | | x | |
| 287 | Tapping | x | | | |
| 288 | Tennis | | | x | |
| 289 | Tennis, serve | | | x | |
| 290 | Three standing broad jumps | | | x | |
| 291 | Time for pulse rate to return to normal after exercise | x | | | |
| 292 | Tracing | x | | | |
| 293 | Traveling rings | | | x | |
| 294 | Tread water | | | x | |
| 295 | Trunk lifting | x | | | |
| 296 | Tumbling | | | x | |
| 297 | Vital capacity | | | x | |
| 298 | Vital index | | | x | |
| 299 | Volleyball, serve | | | x | |
| 300 | Walk, one-half mile | | | x | |
| 301 | Walking | x | | | |
| 302 | Walking heel to toe, in straight line, eyes open | x | | | |
| 303 | Weight | x | | | |
| 304 | Weight throwing | | | x | |
| 305 | Wrestling | | | x | |

In Table 1 the 305 items used in the eighty-nine tests are analyzed to determine the time, knowledge, and equipment required for their administration. Items which satisfied the threefold criteria are designated. When more than a minimum of time, knowledge, and equipment was required this is also indicated.

One hundred and one of the 305 items listed in Table 1 satisfied the criteria in that they required a minimum of time, equipment, and knowledge to administer. Two hundred and four items failed to satisfy the criteria. The causes of failure were as follows:

| | *No. of Items* |
|---|---|
| Required more than a minimum of time | 9 |
| Required more than a minimum of equipment | 169 |
| Required more than a minimum of knowledge | 8 |
| Required more than a minimum of time, equipment, and knowledge | 6 |
| Required more than a minimum of equipment and knowledge | 6 |
| Required more than a minimum of time and equipment | 6 |
| Total | 204 |

Equipment requirements which were more than a minimum accounted for 169, or 83 per cent, of the causes of failure. This is what might be expected, as many of the tests from which these items were taken were designed for use in gymnasia or natatoria.

It was necessary to examine further the 101 items which required a minimum of time, equipment, and knowledge for administration, as the purpose of this study—the construction of a supplementary-screening test—limited satisfactory items to those which were also useful for this purpose. To facilitate discussion, the 101 items were grouped into six divisions. The items, thus grouped, are presented in Table 2.

## Activity Measures

Not all of the thirty-one physical activities which were found to require a minimum of time, knowledge, and equipment were suitable for the purposes of the test. The desired speed in ad-

ministration limited the possible number of activities to one or two events; the use of the test as a premedical screening device prohibited the inclusion of activities which might cause hazards in unselected groups; and the measurement of physical ability required an exercise which tested performance in large-muscle

TABLE 2

ITEMS USED IN TESTS OF PHYSICAL EDUCATION WHICH CAN BE ADMINISTERED WITH A MINIMUM OF TIME, EQUIPMENT, AND KNOWLEDGE

A. *Activity Measures* ($N = 31$)

| Item No. | Test Item |
|---|---|
| 7 | Arms out at the side, horizontal position, well back. The person then leans backward, supported by two other pupils with support at the wrist |
| 63 | Chinning |
| 70 | Deep-knee bend |
| 111 | Front leaning rest, from standing position |
| 116 | Handspring |
| 117 | Handstand |
| 133 | Hop on toes of each foot |
| 135 | Hopping one hundred feet |
| 148 | Jump and reach |
| 152 | Jumping over a horizontal rope, twenty inches high |
| 154 | Jumping, vertical height |
| 155 | Kick for height |
| 156 | Knee raising |
| 160 | Leaning backward, in either standing or sitting position |
| 162 | Leg raising |
| 169 | Lunge with a foil, accuracy |
| 195 | Prone falling |
| 197 | Pulling up part of the weight of the body |
| 206 | Push up part of the body weight |
| 207 | Push up from front leaning rest |
| 211 | Rising on toes |
| 212 | Raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high |
| 216 | Run |
| 228 | Running in place for fifteen seconds |
| 229 | Running in place thirty seconds, 180 steps per minute |
| 247 | Somersaults |
| 259 | Strength, pull up |
| 287 | Tapping |
| 292 | Tracing |
| 295 | Trunk lifting |
| 301 | Walking |

TABLE 2 (*Continued*)

B. *Anthropometric Measures* ($N = 14$)

| Item No. | Test Item |
|---|---|
| 1 | Age |
| 6 | Arms, girth upper |
| 57 | Chest, ninth-rib measurement |
| 59 | Chest, depth |
| 60 | Chest, expansion |
| 61 | Chest, girth in expansion |
| 62 | Chest, width |
| 122 | Height |
| 123 | Height-weight relationship |
| 124 | Height-weight-age relationship |
| 186 | Pelvic breadth |
| 192 | Posture |
| 235 | Shoulder breadth |
| 303 | Weight |

C. *General Measures* ($N = 10$)

| Item No. | Test Item |
|---|---|
| 4 | Appearance, general |
| 45 | Breath-holding |
| 47 | Breathlessness after activity |
| 65 | Color of the skin |
| 68 | Coordination |
| 89 | Endurance |
| 93 | Fatigue after activity |
| 145 | Initiative |
| 187 | Physical ability |
| 248 | Sportsmanship |

D. *Special Senses and Diagnostic Measures* ($N = 8$)

| Item No. | Test Item |
|---|---|
| 66 | Color sense |
| 90 | Eyesight |
| 120 | Hearing |
| 131 | Holding needle in holes of different size |
| 194 | Pressure with thumb over sustentaculum tali |
| 208 | Quickness to respond to a signal by the eyes and ears |
| 242 | Snellen Test Chart (vision) |
| 266 | Swaying of body while attempting to stand motionless |

TABLE 2 (*Continued*)

E. *Cardiovascular Measures* ($N = 12$)

| Item No. | Test Item |
|---|---|
| 55 | Change in heart rate from horizontal to vertical position |
| 74 | Difference in pulse rate before exercise and after forty-five seconds of rest |
| 121 | Heart rate after twenty-five forward body bends in thirty seconds |
| 141 | Increase in heart rate after running in place at rate of 180 steps per minute for thirty seconds |
| 142 | Increase in heart rate after hopping one hundred feet |
| 143 | Increase in heart rate after raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high |
| 199 | Pulse beats for two minutes following exercise |
| 200 | Pulse rate, horizontal |
| 201 | Pulse rate, vertical |
| 202 | Pulse rate, sitting |
| 203 | Pulse rate, after exercise |
| 291 | Time of heart rate to return to normal after exercise |

F. *Stunts* ($N = 26$)

| Item No. | Test Item |
|---|---|
| 10 | Balancing, one deep-knee bend |
| 11 | Balance |
| 33 | Bend and touch one knee to floor, and stand up while grasping other foot behind the body |
| 34 | Bend forward touching the fingers to the floor |
| 64 | Close-walk-stand position |
| 69 | Cross feet, sit down cross-legged, get up (use of arms not allowed) |
| 88 | Elbows to knees from a supine position |
| 92 | Falling |
| 129 | Hold toe of each foot in opposite hand, jump up, and jump free foot over the held foot |
| 149 | Jump into air and clap feet together |
| 150 | Jump into air and make one-half turn |
| 151 | Jump into air and slap both heels with hands behind back |
| 157 | Kneel on both knees (arms folded behind back), get up |
| 158 | Kick right foot so that toes come level with shoulders |
| 209 | Raise right foot from floor to side twelve inches, jump sideways to right, hitting left heel against right heel while in the air |
| 210 | Raise right or left foot from the floor |
| 240 | Side fall position, raise leg |
| 241 | Sit up |
| 251 | Squat on heels with feet together, jump to straddle, stand on heels |

TABLE 2 (*Continued*)

| Item No. | Test Item |
|---|---|
| 253 | Stand on left foot, bend forward and place hands on the floor, raise right leg and stretch it back, touch head to floor |
| 254 | Stand with both feet tight together, bend down, extend both arms between the knees around the ankles, hold the fingers together in front of ankles |
| 255 | Stand on left foot, right foot extended, sit down on heel of left foot without touching right foot or hand to floor, stand up |
| 256 | Stand on left foot, right foot against inside of left knee, shut eyes, hold position |
| 264 | Stunts |
| 265 | Supporting body on hands, knees against elbows |
| 302 | Walking, heel to toe, in straight line, eyes open |

activities. These activities were further examined in the light of the limitations, and unsuitable items were rejected. Six activities were found which were suitable for the test. They were: front leaning rest from standing position, Item 111; hopping one hundred feet, Item 135; jump and reach, Item 148; jumping, vertical height, Item 154; raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high, Item 212; running in place for fifteen seconds, Item 228.

It was decided at this point of the study to retain all suitable activities and to select later, by experimentation, the items which contributed most to the development of the test.[1]

## Anthropometric Measures

These items are important measures of health, and are regularly used in the medical examination. However, they are static measures of the individual at rest, and therefore do not pertain to the purpose of this study, namely, the measurement of important aspects of functional condition[2] of the individual in response to large-muscle activities. These items were deemed unsatisfactory and therefore were discarded.

[1] The experiments used in selecting the most suitable items are described on page 45.

[2] See page 6. To supplement the static tests of the medical examination, functional tests are necessary.

## General Measures

With the exception of Items 45, 47, 187—breath-holding, breathlessness after activity, and physical ability, these items are used as estimates in the original tests, and no quick objective measure of these qualities is available. Items 45 and 47 are apparently intended to measure the functional condition of the respiratory system. As the element of volition is present in the former item, it was discarded in favor of breathlessness after activity.

## Special Senses and Diagnostic Measures

The eight items in this group are measures of specialized functions and specific conditions. Some of these functions, such as vision and hearing, are very important, and their measurement is included in the medical examination. In general, however, the areas measured by these items are so specific and limited that their use in a general survey examination is not advisable. Collectively, these items constitute an important, specialized investigation—the neurological examination.

## Cardiovascular Measures

Twelve cardiovascular measures were found. These items appeared to offer considerable promise, for they are quick, simple measures of important aspects of physical condition. It was necessary, however, to eliminate numerous duplications and meaningless variations and to rephrase the remaining items to include all essential variations. Item 202—pulse rate, sitting—was eliminated, as the rate in this position is taken only as a matter of convenience, and the diagnostic value of this item is included in the items: pulse rate, horizontal, and pulse rate, vertical. Item 200—pulse rate, horizontal—was omitted as a separate item, since it is included in Item 55—change in heart rate from horizontal to vertical position. The five variations of pulse rate after exercise—Items 121, 141, 142, 143, and 203—were consolidated into Item 203—pulse rate after exercise. The three variations of the time

required for the pulse rate to return to normal after exercise—Items 74, 199, and 291—were consolidated into Item 291—time for pulse rate to return to normal after exercise.

The four forms finally retained were: pulse rate, vertical (Item 201); change in heart rate from horizontal to erect position (Item 55); pulse rate (immediately) after exercise (Item 203); time for pulse rate to return to normal after exercise (Item 291).

## Stunts

The possibilities of the items of this type when used in a battery have been adequately developed by David K. Brace. [19] The time required for the administration of the Brace test, however, as mentioned in Chapter II, prohibits its use in this study. Individually, the items did not appear to offer promise, in view of the fact that they test special abilities in specific situations. These items were rejected.

Of the 101 items which satisfied the minimum requirement criteria, twelve were suitable for use in a supplementary-screening test. These twelve items are listed in Table 3. The first six are activities, the remaining six consist of two general measures (breathlessness after activity, and physical ability) and four pulse rate items.

The value of the method used in selecting suitable items rests primarily upon the assumption that, in their published tests, the workers in health and physical education have indicated their judgments of the test techniques available for this purpose. The measurement of the several aspects of physical capacity has engaged the attention of numerous investigators over a long period of time. Among these workers are physicians, physiologists, and physical educators who have served as clinicians, research specialists, and teachers. All of these methods are represented in the tests analyzed. The number of items used—305—indicates the extent and variety of conclusions and suggests that further variation is not the immediate need.

The method used for selecting suitable techniques was not entirely objective, and it is possible that other items might have been

TABLE 3

ITEMS USED IN TESTS OF PHYSICAL EDUCATION WHICH ARE SATISFACTORY FOR A SUPPLEMENTARY-SCREENING TEST LIMITED TO A MINIMUM OF TIME, EQUIPMENT, AND KNOWLEDGE TO ADMINISTER ($N = 12$)

| Item No. | Test Item |
|---|---|
| 111 | Front leaning rest, from standing position (at top speed) |
| 135 | Hopping one hundred feet |
| 148 | Jump and reach |
| 154 | Jumping, vertical height |
| 212 | Raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high |
| 228 | Running in place for fifteen seconds |
| 47 | Breathlessness after activity |
| 187 | Physical ability |
| 201 | Pulse rate, vertical |
| 55 | Change in pulse rate from horizontal to vertical position |
| 203 | Pulse rate (immediately) after exercise |
| 291 | Time for pulse rate to return to normal after exercise |

included by other investigators.[3] Probably the most debatable of the excluded items is the measurement of blood pressure by means of the sphygmomanometer. Although this technique is quickly administered and the necessary equipment, usually found only in the possession of physicians, can be obtained at reasonable cost, it was excluded because of the knowledge and caution required for its proper use. The method of administration is relatively simple, but it is very difficult for the examiner to avoid making statements regarding the significance of the results, for there is much popular interest in this measure. If measurement of blood pressure by a sphygmomanometer were included in our test, which is intended not only for physicians but also for lay workers, it would follow that the necessary equipment would have to be furnished and the method taught to a large number of relatively unselected individuals. Without adequate means for preventing unwarranted and invalid diagnosis, this seemed inadvisable; therefore this technique was listed as unsuitable for use in the present study.

The purpose of the analysis was to isolate test items or tech-

[3] Whenever there was reasonable doubt whether a given item satisfied the criteria, the item was included in the satisfactory group.

niques for the measurement of physical capacity which required a minimum of time, knowledge, and equipment to administer. The method employed was satisfactory to the extent that twelve suitable items were found.

## Summary

The situation for which the proposed test was intended restricted possible items to those which could be administered with a minimum of time, equipment, and knowledge. The major problem was therefore the identification of a sufficient number of suitable items.

An impartial survey was made of the published tests in physical education. Eighty-nine tests were found and these were analyzed to determine the items or techniques used. Three hundred and five items were found. Each item was examined to ascertain its administration requirements in terms of time, equipment, and knowledge. One hundred and one items (each administered in two minutes or less) which did not require medical diagnostic ability or extensive equipment were retained. Other items were rejected.

The intended use of the test as a supplementary-screening device to be given prior to the medical examination further limited the items to those which (1) measured important areas of physical capacity; (2) were not given in the medical examination; and (3) were not too strenuous for use in unselected groups. The 101 items which passed the time, equipment, and knowledge requirements were further examined in light of these additional limitations. Twelve items were found which satisfied the criteria. Six were activities, and, as was previously explained, it was decided to retain all temporarily and later, by experimentation, to select the most suitable.

# CHAPTER III

## BUILDING THE ITEMS INTO A TEST

THE result of the investigations undertaken up to this point was the selection of a number of suitable items. The next problem was to build these measures into a test. The solution of this problem required: (1) Consideration of possible methods. (2) Study of the characteristics of health data as they pertained to the methods which might be used. (3) Search for a suitable criterion. (4) Selection of a method (*a*) of construction and (*b*) of administration. These steps will be described in this chapter.

### POSSIBLE METHODS

Two methods could be employed in construction of the test: (1) items could be weighted and combined to produce a single numerical score; or (2) the significance of each item could be kept separate and individual unweighted scores used as the test.

#### WEIGHTING AND COMBINING TEST ITEMS

This method of weighting and combining test items has been employed in education [70], physical education [34], and many other fields [85], and many valuable tests have been thus developed. A linear regression equation is ordinarily used to determine the significance of each item, and the weighting each item should receive, in order that the battery may have maximum predictive value. The proper use of this technique requires, however, (1) that there be a valid criterion for the traits or characteristics to be measured; (2) that the zero order coefficients be computed from data in which the regression is linear,[1] or approximately

[1] Linear regression is defined by Garrett as follows: "When the means of the arrays of successive columns or rows in a correlation table follow straight lines (exactly or approximately) the regression is called 'linear' and the relation between the two sets of measures or scores is a 'straight line relation.'" [51: 203]

linear; and (3) that numerically equal scores have equal meanings, irrespective of the particular contributions made by the several items.

The first two requirements follow from the method of the regression equation, which is to predict values of criterion scores from the predetermined correlations of the items with that previously established criterion. When the relationship between the two sets of scores is other than a straight line relationship, the difficulties of prediction are greatly increased, as new values are found by projection from known values or points. The third requirement is necessitated by the use of a single numerical score to reflect the values of all items used in the equation. Any given score may be the result of a large number of different combinations of items. The data must be of such character that all combinations which produce the same score have equal value. For example, if two items are used in an equation, two equal scores must have equal value, in spite of the fact that the first score may be derived from a combination of two units of one item and one of another, and the second score from the combination of one unit of the first item and two of the second.

### TREATING ITEMS AS SEPARATE TESTS

In this method no attempt is made to combine or weight the individual items—each item is treated as a separate test and its score, unaltered, is expressed in the result. The outcome is an outline or profile of the subjects' abilities as indicated by the individual items, and the full diagnostic value of each item is retained. This method is used in the medical examination and in many medical and diagnostic tests; however, it does not indicate validity of the items, and other means must be employed for this purpose.

Characteristics of the data were investigated to ascertain which of the two possible methods of test construction was more suitable.

## Characteristics of Health Data

A preferable method of building the test would be to weight and combine the items by the use of the regression equation, for the

validity of the items and their maximum predictable value would thus be obtained. Since the proper use of this technique required that the three previously mentioned conditions be present, it was necessary to ascertain whether the data of this study met these requirements. An examination disclosed the following characteristics of the data—non-linearity, essentiality of certain body functions, and importance of sets of symptoms or syndromes.

### NON-LINEAR CHARACTER OF HEALTH DATA

An examination was made of the relationship known to exist between health and several of the measures selected for the proposed test. It was found that the normal range of the vertical pulse rate is from approximately sixty to one hundred beats per minute [121: 432], and that the two extremities—slow rate and fast rate—are pathological conditions. Bradycardia (slow pulse) is characteristic of acute nephritis, fatty heart, and fibroid myocarditis [112: 113], and tachycardia (rapid pulse) is characteristic of fever and valvular diseases of the heart [112: 112]. The relation of the vertical pulse rate to health was, therefore, non-linear, for a linear relation would require that the more frequent the pulse the better the health, if the relation is positive; or, the slower the pulse the better the health, if the relation is negative. If the curve could be plotted, with pulse frequency on the horizontal axis and health on the vertical axis, it would undoubtedly be found that the relationship between health and pulse frequency is non-linear.

A similar analysis of the relations between health and pulse rate increase after exercise, pulse rate reaction after exercise, and breathlessness after activity indicates that these relations are non-linear. The relations between health and the pulse rate reaction after exercise, and the pulse rate return after exercise, are also curvilinear. It is well known [33: 277-78] [79] that an exaggerated increase in pulse frequency is a characteristic of "Soldiers Heart" or D. A. H. (disordered action of the heart) and that no increase in pulse frequency after exercise indicates that the heart at rest is functioning at its maximum frequency. [17: 92] Therefore, both the absence of an increase in pulse frequency after

exercise and an exaggerated increase are associated with poor health. Similarly, with the pulse rate return after exercise, Kahn [62] has shown that very rapid returns are found in cardiacs, and others [79] [33: 274-75] have found a delayed return characteristic of disordered action of the heart. Both extremes are, therefore, associated with pathological condition and the relationship is curvilinear.

### ESSENTIALITY OF CERTAIN BODY FUNCTIONS

There are numerous factors of health, such as the heart beat, the respiration rate, and the diastolic blood pressure, which must function within certain limits if life is to be maintained. When these essential factors are used as items in a regression equation, their improper function may be apparently compensated for by superior performance in other items and a numerical total may be obtained which does not indicate the true condition, for the failure of one or more of these essential factors vitiates the score irrespective of the magnitude or the performance in the other factors.

### IMPORTANCE OF SETS OF SYMPTOMS OR SYNDROMES

Medical science has long been aware that particular sets or combinations of symptoms have greater significance and diagnostic value than the individual symptoms would indicate. For example, recent loss of weight, night sweats, and persistent colds occurring together are much more significant than the individual symptoms, for the combination is indicative of incipient tuberculosis. The significance of such sets of symptoms may be lost when the items of a test are combined into a single numerical score. As an illustration, let us assume a simple health scale consisting of 25 items, with 100 as the maximum score from which 4 points are deducted for each defect. Individual A is overweight, has flat feet, and poor musculature—his score is therefore 88. Individual B has an infected throat, elevated temperature, and a skin eruption on his chest—his score is also 88. These individuals have equal scores; however, the symptoms found in Individual B have collectively a significance far greater than those found in Individual A, for they indicate an infection, possibly scarlet fever.

### A Suitable Criterion

The difficulty of selecting a suitable criterion was greatly increased because physical capacity is not a single factor but the total of numerous factors, including the presence or absence of limiting defects and the ability to perform large-muscle activities. A suitable criterion must measure these different aspects and combine the results into a single numerical score. The items of the medical examination are valid measures of defects, and there are also valid measures of physical ability. Unfortunately for the development of a criterion, the results of the medical examination are expressed in terms of individual tests and items, and no valid method exists for combining these results into a numerical score. The best that has been accomplished is a categorical rating by the examining physician. The combining of these ratings with numerical physical ability scores to produce a meaningful total would be a difficult, if not an impossible, task for no technique is available. A suitable criterion was therefore not developed for expressing the results of the medical examination in a numerical score or for combining medical results with physical ability scores.

### Selection of Method of Construction

The two possible methods of construction were now considered in relation to the findings of the foregoing investigations. The failure to find or develop a suitable criterion prevented the use of the regression equation technique for discovering the optimum weights each item should receive and the predictive validity of the results. The second requirement for the regression equation —linearity of data—was also not met, for the data were found to exhibit non-linear characteristics. The two other peculiarities found, namely, essentiality of certain body functions, and the importance of sets of symptoms or syndromes, indicated that with these data numerically equal scores may not have equal meanings, a possibility which vitiated the third requirement. Thus, none of the three requirements for the regression equation were met in the data.

The method decided upon was to treat each item as an individual test and to keep separate the significance of each item. This, the second method of construction, was necessitated by the unsuitability of the data for the use of the regression equation. Also, the selected method retains the full diagnostic value of each item—a decided advantage, as the proposed test is primarily an instrument for diagnosing questionable physical condition.

### Selection of Method of Administration

Up to this point in the study, the following had been accomplished:

1. Twelve suitable items had been found.
   *a.* Six items that satisfied all requirements had been isolated; namely, 47, breathlessness after exercise; 187, physical ability; 201, pulse rate, vertical; 55, change in pulse rate from horizontal to vertical position; 203, pulse rate immediately after exercise; 291, time for pulse rate to return to normal.
   *b.* Six suitable activities had been found: 111, front leaning rest from standing position; 135, hopping one hundred feet; 148, jump and reach; 212, raising body five times in fifteen seconds; 228, running in place fifteen seconds; 154, jumping vertical height.
2. The decision to treat each item as a separate test had been reached.

The method of administering the items was next considered. The simplest plan of administration, and the one generally followed, is to select suitable test exercises for each type of response measure. However, this method did not seem feasible for the purposes of this study. Its use would require four exercises, as four of our six suitable items (47, 187, 203, 291) measure reactions secured after exercise, the remaining two items (201 and 55) being taken with the subject at rest. It seemed obvious, therefore, that if one test exercise could be developed which would elicit the four desired responses, a considerable saving in adminis-

tration time could be achieved. Development of such an exercise was attempted by experimenting with the six suitable activities.

The first activity experimented with was the fifteen-second run-in-place used in the Michigan State Test—Item 228. In several respects this movement was ideal, for it is simple and well known. Two of the items—pulse rate immediately after exercise, and time for pulse rate to return to normal—were readily measurable, but because it was impossible to secure reactions suitable for the measurement of the other items, the movement was abandoned. Each of the remaining six activities was experimented with, and all, with the exception of Item 111—a four-count front leaning rest, executed from standing position—were found unsatisfactory because no method could be developed for measuring the four reactions after exercise required by Items 47, 187, 203, and 291.

Different repetitions of Item 111 were tried, and four repetitions at maximum speed were found to be satisfactory in that, without creating unnecessary hazards, the effort induced was sufficiently strenuous to produce mild fatigue and breathlessness in subjects who were in poor physical condition. Also, the pulse rate return after exercise, in normal individuals, was within the desired range of two minutes.[2] Consequently, four repetitions of the front leaning rest exercise were chosen for the test activity.

The items were standardized upon this exercise thus:

1. The pulse rate immediately after the test exercise was used for Item 203, pulse rate immediately after exercise.
2. The time required for the pulse rate to return to normal after the test exercise was used for Item 291, time for pulse rate to return to normal after exercise.
3. The degree of breathlessness after the test exercise was used for Item 47, breathlessness after exercise.
4. The coordination required in executing the test exercise was used for one phase of Item 187, physical ability—the physical ability to execute the movements.

[2] Our experiments with pulse rate reaction after exercise showed that the desirable range was within two minutes, as repeated counting of the pulse over a long period of time tended to excite the subject and thereby make the pulse rates unreliable.

5. The time required to execute the four front leaning rests was used as a second phase of Item 187, physical ability—the ability to perform large-muscle activities with speed.

6. As Items 201 and 55—pulse rate, vertical, and change in pulse rate from horizontal to vertical position—are taken at rest, the method of administering the items was completed.

To distinguish between the two phases of physical ability, the title of the first phase, the performance or execution of the standard exercise, was changed to "limited motor movement." The term "physical ability" was reserved for the second phase—the speed with which the exercise is performed.

## Summary

In this chapter the building of the selected items into a routine was outlined. Two methods were considered: The significance of the items could be found by means of the regression equation technique and the items weighted and combined to produce a single numerical result; or, the items could be treated as separate tests.

No suitable criterion could be found, and examination of data revealed peculiarities which made the use of the regression equation inadvisable. The items were therefore treated as separate tests.

A single test exercise, consisting of the four front leaning rests executed from standing position, was developed. All items requiring for their measurement the performance of a suitable large-muscle movement were standardized upon this single test exercise.

The test, as finally developed, consisted of seven items, two of which measured responses secured with the subject at rest, and five of which measured reactions to exercise. One test exercise was used to secure these five responses. Each item was treated as a separate test, and its score, unaltered, was used in the final result. The seven items were as follows: (1) Pulse rate, vertical. (2) Change in pulse rate from horizontal to vertical position. (3) Pulse rate immediately after exercise. (4) Time for pulse rate to return to normal after exercise. (5) Breathlessness after exercise. (6) Limited motor movement. (7) Physical ability.

# CHAPTER IV

## DETERMINATION OF NORMAL AND QUESTIONABLE SCORES

At this point in the study the selection of seven suitable items had been completed and a method of using them as a screening test had been devised. Three problems now remained. These were:

1. The determination of the normal and questionable reactions in each of the seven selected items.
2. The selection of critical scores when the items are used as a screening test.
3. The determination of the values and limitations of the resulting test.

In this chapter are presented the results of studies undertaken to establish the normal and questionable reactions, and a discussion of the method used in scaling the items. In Part II (page 109) the methods used to establish the values and limitations of the completed test are discussed.

### Consideration of Methods

In few if any studies can the ideal be achieved, and the methods used are a compromise between the most desirable and the possible. In this study the peculiarities of health data[1] and the absence of an inclusive objective test of health made necessary numerous compromises in method. Statistically, one much used method of finding the significance of the reactions or scores in the seven selected items would be to set up two mutually exclusive groups (e.g., individuals who are in good health, and individuals who are not), and by means of the biserial method of correlation

[1] See pages 40-42 for a discussion of peculiarities of health data.

to determine the relationship between the scores of the two groups. The results would be a series of correlation coefficients. The less the scores of the two groups overlap, the higher (nearer to 1) the coefficient would be; the more these groups overlap, the lower (nearer to 0) the coefficient would be. These relationships, thus expressed in quantitative terms, would then be used as a basis for developing a regression equation which would give, with maximum predictive value, the most probable health of a subject from a knowledge of his scores in the seven selected items. Unfortunately, as previously mentioned,[2] the assumptions underlying the proper use of the regression equation could not be met in our data, and this method could not be used.

The use of the biserial *r* without the regression equation was next considered. The two groups might have identical means, so that the biserial *r* would be zero, and yet one group might be made up only of individuals with scores near the middle of the range while the other group might scatter widely. Consequently, this method would not reveal what it is necessary to know, and it was therefore rejected.

### THE METHOD USED

The procedure selected for determining the significance of scores consisted of the following steps:

1. Two groups, (A) individuals in good or excellent condition, and (B) individuals not in good or excellent condition, were established.
2. On each test, the frequency distributions of the two groups were compared to ascertain the reactions characteristic of individuals in both groups.
3. A comprehensive survey of the literature was made, and comparable data involving approximately 4,000 cases were obtained.
4. Opinions of other investigators were reviewed.
5. Criteria for "normal" and "questionable" reactions or rates were established. These were:

[2] See pages 39-40 for discussion of the assumptions underlying the proper use of the regression equation.

*Normal Reactions*

*a.* Reactions are found in individuals in good or excellent condition.

*b.* Investigators are in agreement that rate is normal.

*Questionable Reactions*

*a.* Reactions are not found in individuals in good or excellent condition.

*b.* Reactions are found in individuals not in good or excellent condition.

*c.* Reactions are found in pathological individuals.

*d.* Investigators are in agreement that the rate is a pathological symptom.

6. All data and opinions were considered, and rates or reactions which satisfied the criteria for "normal" and "questionable" rates were designated.

7. Critical scores, that is, scores at which the significance of the items changed, were established as follows:

*a.* The critical scores designated by the criteria were adjusted so that 5 per cent of the good condition cases fall within the "questionable condition" range.[3]

These studies deal primarily with 455 men and boys who were members of the physical education department of the Young Men's Christian Association. Their ages ranged from twelve to sixty-four years, the arithmetical mean being 26.2 years, the mode 17.5 years, and the standard deviation 8.5 years. Complete data were not available in all cases, hence the number of cases studied for the different items varies.

Physical condition was determined by means of medical examinations administered by registered physicians. The examination used was that recommended by the American Medical Association for the examination of apparently healthy individuals. [2] At the completion of each examination, the physician summarized the results and noted (1) "Good, or excellent, condition" if no

[3] See pages 52 and 93 for further discussion of critical scores.

defects were disclosed which impaired health, and also if the muscular condition was good; or (2) "Not in good or excellent condition" if one or more defects were disclosed which might impair health, or if the muscular condition was not good.

This method of differentiating the two groups was not ideal in that the validity of the results rests upon the diagnostic ability and judgment of the examining physician, but, in the absence of an inclusive objective test of physical condition, this method—the judgment of a trained, experienced physician—appeared to be the best substitute. In the other studies which are cited the medical examination was also used to determine physical condition.

The seven selected items were administered prior to the medical examination. The physical condition of the subject was unknown at this time. Examinations were given during the afternoon and evening at the subject's convenience—chiefly between eight and ten o'clock in the evening. Efforts were made to establish rapport and to place the subject at ease in order that emotional stimulation might be avoided. Pulse rates were determined from palpation of the radial artery. The rate was counted for each fifteen seconds and multiplied by four to obtain the rate per minute. Time was measured by means of a fifth-second stop watch. Other procedures followed usual examination methods.

## BASIC PREMISES

The division of reactions or scores into "normal" and "questionable" was necessarily arbitrary, for in unselected groups health does not exist as a dichotomy of good or bad, but presents a continuous series from one extreme to another. The premises upon which the use of the previously outlined method for determining normal and questionable reactions was based were as follows:

### *Normal Reactions*

Webster [143] defines normal as "according to, constituting, or not deviating from, an established norm, rule, or principle; conformed to a type, standard, or regular form; performing the proper functions; not abnormal; regular; natural; analogical." In determining physical condition, the physician administered fifty-six tests in each of which there were recognized norms or normal reactions. The good condition group

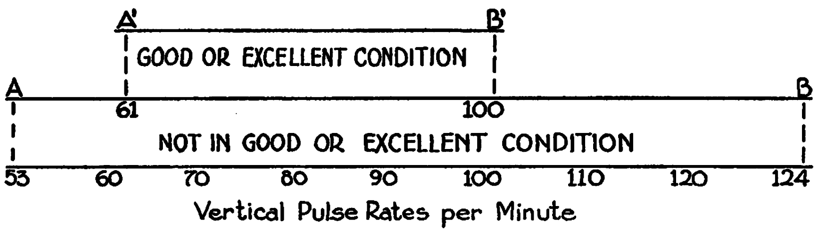
was composed of those individuals who did not deviate from the norms of health established by the medical profession. They were, therefore, by definition, "normal" individuals. The basic assumption was that the reactions exhibited by these "normal" individuals in the seven items of the test constitute "normal" reactions because they are exhibited by "normal" individuals.

### *Questionable Reactions*

Rates not found in normal individuals were considered "questionable" reactions, i.e., reactions which indicate questionable physical condition, for such rates (1) do not satisfy the criteria of normal rates; and (2) are found only in individuals not in good condition, and are therefore peculiar to such individuals.

## METHOD ILLUSTRATED

The method used in determining normal and questionable reactions may be illustrated by the use of reactions found for Item I: Vertical Pulse Rates. These data are shown in Figure 1.




A–B Rates per minute of individuals not in good or excellent condition (one or more defects which impair health).

A′–B′ Rates per minute of individuals in good or excellent condition (no defects). Normal range: rates found in normal individuals—individuals judged normal in fifty-six tests of medical examination.

A–A′, B–B′ Questionable range: rates not found in normal range—found only in individuals not in good or excellent condition.

FIGURE 1

Vertical Pulse Rates of Individuals (1) In Good Physical Condition, and (2) Not in Good Physical Condition

The vertical pulse rate of individuals in good or excellent condition (A′–B′), as will be seen from Figure 1, ranges from 61

to 100 beats per minute. The range for individuals not in good or excellent condition (A–B) is more extensive—from 53 to 124 beats per minute. In the latter range there are two types of reactions: (1) rates from 53 to 60 and from 101 to 124 beats per minute (A–A′, B–B′), which are considered questionable reactions as they were found *only* in not in good condition cases; and (2) rates from 61 to 100, which are considered normal reactions as these are the rates found in good condition cases.

The presence of normal vertical pulse rates in the group not in good condition is due to the criterion used for selecting this group—the presence of one or more defects which may impair health. Many of this group were so classified because of defects other than those associated with vertical pulse rates. These individuals, therefore, exhibited normal vertical pulse rates. Similarly, with each item studied there will be cases not in good condition who exhibit normal reactions.[4] To have all cases not in good condition exhibit questionable reactions in all seven items, it would have been necessary to define questionable physical condition, not as the presence of one or more defects which may impair health, as was done, but as the presence of defects sufficiently grave to cause abnormal reactions in *all* seven selected items—a difficult, if not an impossible, basis of selection, as abnormal reactions in these items had not been determined at that time.

### CRITICAL SCORES

The final problem in determining normal and questionable reactions was the selection of the method for locating that score at which, in most probability, the significance of the reaction would be considered to change. As previously explained, the method used for defining reactions placed the critical scores at the extremities of the good condition range. Although this method indicated a definite score in the data, it was not satisfactory for indicating the critical scores of reactions, in general, for the following reasons:

[4] A study of the relationship between defects disclosed by medical examination and by seven items of the test is given on pages 118 to 125.

1. The extremities of a distribution are relatively unreliable. That is to say, if the reactions of a similar, but different, group of subjects were tested a different range might be found.

2. In several of our good condition groups the number of cases was not of sufficient size to insure statistically reliable results. Although over four hundred subjects were examined, the basis for selecting good condition cases was so stringent that relatively few such cases were found.

3. In any small sample the range and all measures of variability tend, on the average, to be less than those in the population from which the sample is drawn.

The effect of these factors was to decrease the reliability of the critical scores indicated by the data. The steps taken to overcome the influence of these factors were: (1) increasing the number of cases; (2) considering expert opinion; and (3) placing the critical score so that 5 per cent of the good condition cases were excluded from the normal range.

Related data from numerous other studies were secured. A comprehensive survey of the literature was made, and comparable data for several thousand cases were thus collected. These data served not only to increase the number of cases, but also to increase the reliability of the study by making it more representative. Studies of pathological conditions, and opinions of other investigators were also reviewed. Thus, the location of the critical scores was based upon (1) a primary study of 455 cases; (2) additional studies of approximately 4,000 cases; (3) pathological data; and (4) opinions of other investigators.

Six of the seven items used in the proposed test have been used and studied by many investigators over a long period of time. The conclusions of these investigators, many of whom are recognized authorities, were recorded and employed as a check on the conclusions indicated by the data of the present study.

In unselected groups, as previously stated, health does not exist as a dichotomy of good or bad, but presents a continuous series from one extreme to another. It therefore follows that the limits of the range for persons in good or excellent condition can-

not be sharply and precisely defined. In order to insure a margin of safety, the critical scores in each item were placed within the good condition ranges indicated by the data, so that 5 per cent of the good condition cases fall within the "questionable condition" range.[5]

## Studies Undertaken to Establish Normal and Questionable Reactions

Each of the seven items of the test is considered separately in the following discussion. For convenience, the presentation has been arranged under four headings: (1) General Statement; (2) Data; (3) Discussion; and (4) Summary and Conclusion. An attempt has been made to focus the discussion upon the criteria for normal and questionable physical condition.

### *Item 1: Vertical Pulse Rates*

#### GENERAL STATEMENT

Recent research has tended to minimize the importance of the pulse rate as an indication of physical condition. It is interesting to note, however, that the pulse rate has been studied and its significance recognized since the third century before Christ. "It is reported that Herophilus placed such great faith in the pulse rate as a significant symptom, that he built a water clock (clepsydra) whose capacity corresponded to the normal number of pulse beats for every age period. It was his custom to set up the water clock at the bedside and to feel the pulse of the febrile patient. The greater the number of pulse beats, beyond the normal figure, that were counted up to the time that the water clock was completely filled, the greater, according to him, was the acceleration of the pulse, i.e., the fever was stronger or weaker." [123]

It was not until the early part of the nineteenth century, when the second hand was regularly incorporated in watches for everyday use, that the pulse numeration became a routine procedure

[5] The reasons for the use of this method are discussed on pages 93-96.

among physicians. [4] Since then it has been used constantly, and it is now recognized that "Examination of the arterial pulse is of great diagnostic importance because it informs us of many things, such as the cardiac innervation, the force of the heart, the blood pressure, and the condition of the peripheral arteries, and sometimes suggests the existence of valvular diseases of the heart or fever." [112: 107]

The determination of the normal range of the standing or vertical pulse is complicated, as the heart rate fluctuates in response to manifold extrinsic and intrinsic stimuli. McCurdy [75] has shown that the normal pulse rate is lowest in the morning and highest in the afternoon. The rate has also been found to vary with the seasons of the year, the lowest rate occurring in winter. [54], [13], [32] Loss of sleep [148] and increase in altitude [118] tend to increase the rate; variations in air and water movement about the body [66] have also been found to increase the rate. Primarily, the heart rate is determined by the automaticity of the sinus node. These rhythmic discharges are governed by many factors, including alterations in the chemical composition of the blood, some of the internal secretions, the temperature of the blood, and the balanced activity of the vagus and sympathetic nerves. When disease is present alterations occur in the many factors that control the heart rate. [17: 116-17]

## DATA

In Table 4 the results of the investigations of this study of vertical pulse rates are presented. In Table 5 supplementary data are given.

## OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning tachycardia and bradycardia follows.

1. *Rapid pulse rates* (Tachycardia)

"In diseases, in which the heart is affected, the heart rate is usually rapid, and often may be used as an index of the severity of the underlying cardiac disturbance. Such tachycardia may arise from injury to

## TABLE 4

### Vertical Pulse Rates—Primary Study*

| Pulse Frequency Per Minute | Number of Cases: In Good or Excellent Condition | Number of Cases: Not in Good or Excellent Condition | Per Cent of Group: In Good or Excellent Condition | Per Cent of Group: Not in Good or Excellent Condition |
|---|---|---|---|---|
| 124 | | 2 | | .5 |
| 120 | | 2 | | .5 |
| 116 | | 3 | | .7 |
| 112 | | 6 | | 1.5 |
| 108 | | 3 | | .7 |
| 104 | | 4 | | 1.0 |
| 100 | 3 | 19 | 3.9 | 5.0 |
| 96 | 5 | 23 | 6.6 | 6.6 |
| 92 | 7 | 38 | 9.2 | 10.0 |
| 88 | 8 | 29 | 10.5 | 7.6 |
| 84 | 15 | 79 | 19.8 | 20.8 |
| 80 | 13 | 56 | 17.2 | 14.8 |
| 76 | 7 | 45 | 9.2 | 11.9 |
| 72 | 8 | 44 | 10.5 | 11.6 |
| 68 | 8 | 4 | 10.5 | 1.0 |
| 64 | 2 | 10 | 2.6 | 2.6 |
| 60 | | 11 | | 2.9 |
| 56† | | 1 | | .3 |
| Total | 76 | 379 | 100.0 | 100.0 |
| Range | 61–100 | 53–124 | | |

| | | | Difference | Standard Error of Difference |
|---|---|---|---|---|
| Mode | 84 | 84 | 0. | |
| Median | 82 | 82.94 | .94 | 1.5‡ |
| Mean | 81.68 | 83.74 | 2.06 | 1.4 |
| Standard Deviation | 9.12 | 11.52 | 2.40 | .99 |

(Correlation of Age with Pulse Rate — All Cases $r$ = .0064)

* This study is described on pages 49–50.
† Midpoint of interval.
‡ The formulae used in computing the standard deviations of the differences were as follows:

$$\text{Mean: } \sigma_{M_1 - M_2} = \sqrt{\frac{s^2}{n_1} + \frac{s^2}{n_2}}, \text{ where } s^2 = \frac{n_1 s^2_1 + n_2 s^2_2}{n_1 + n_2 - 2}.$$

$$\text{Standard Deviation: } \sigma_{s_1 - s_2} = \sqrt{\frac{s^2}{2n_1} + \frac{s^2}{2n_2}}, \text{ where } s^2 \text{ is as above.}$$

$$\text{Median: } \sigma_{\text{Mdn}_1 - \text{Mdn}_2} = \sqrt{\sigma^2_{\text{Mdn}_1} + \sigma^2_{\text{Mdn}_2}}.$$

TABLE 5: VERTICAL PULSE RATES—SUPPLEMENTARY DATA

| Investigator | *N* | Sex | Age Group | Description of Subjects or Disease | Range of Vertical Pulse Rate |
|---|---|---|---|---|---|
| A. Schneider and Truesdell [121: 432] | 144 | M | Young adults | Good condition | 63–111 |
| | 204 | M | Young adults | Good condition | 60–99 |
| B. Schneider and Truesdell [121: 432] | 2,000 | M | 18–42 (24.8—Mean) | Unselected | 51–147 |
| | 200 | M | Young adults | Unselected | 63–126 |
| Osborne [93] | 181 | M | Prepubescent | Unselected | 50–120 |
| | 638 | M | Pubescent | Unselected | 50–148 |
| | 150 | M | Postpubescent | Unselected | 52–126 |
| C. Boas and Gold-schmidt [17: 123] | 1 | F | 21 | Myocarditis | 100–142 |
| [17: 127] | 1 | F | —* | Graves' Disease | 100–110 |
| | 1 | F | — | Graves' Disease | 90–100 |
| | 1 | M | — | Graves' Disease | 110–120 |
| | 1 | F | — | Graves' Disease | 90–100 |
| | 1 | M | — | Graves' Disease | 110–120 |
| | 1 | M | — | Graves' Disease | 110–120 |
| | 1 | F | — | Graves' Disease | 110–120 |
| | 1 | F | — | Graves' Disease | 120–140 |
| [17: 132] | 1 | F | 35 | Neurocirculatory asthenia | 100 |
| | 1 | F | 14½ | Neurocirculatory asthenia | 100–140 |
| | 1 | M | 43 | Neurocirculatory asthenia | 120–140 |
| [17: 133] | — | — | — | Auricular fibrillation | 100–200 |
| Vierordt [139: 237] | — | — | — | Diseases of heart muscle, especially in fatty heart, also fibroid myocarditis | 36–48 |
| | — | — | — | In hepatogenic icterus | 48 or less |
| D. Bramwell and Ellis [21] | | | | Olympic athletes: | |
| | 18 | M | Mean 22 | Sprinters | 58–76 |
| | 16 | M | Mean 23 | Middle-distance runners | 49–76 |
| | 15 | M | Mean 24 | Long-distance runners | 46–64 |
| | 28 | M | 25–35 | Marathon runners | 50–67 |
| | 7 | M | | Cyclists, sprinters | 53–76 |
| | 9 | M | | Cyclists, long distance | 51–73 |
| | 15 | M | | Weight lifters | 55–106 |

* Dash (—) indicates data not given.

the heart itself; it may be an adaptation to increased work placed on the heart; it may be determined by increased metabolism or by fever; it may be only a manifestation of increased reflex excitability of the heart, due either to an exaggerated sensitivity of its nervous pathways or to an unusual number or intensity of the peripheral or visceral stimuli that reflexly affect the heart." [17: 117]

The specific disorders usually associated with a rapid pulse are: fever, infections of the heart or nerves, valvular diseases in the stage of disturbed compensation, endocarditis, dislocation of the heart, pericarditis, exophthalmic goiter, nervous palpitation, and nervous tachycardia. [112: 112]

2. *Slow pulse rates* (Bradycardia)

In general the following diseases are associated with bradycardia: certain diseases of the heart, especially in the fatty infiltrated heart and sclerosis of the coronary arteries, compensated aortic stenosis, acute cerebral pressure. [112: 113]

"A pulse below 58 or 60 beats per minute should be considered slow, and anything below 50 should be considered abnormally slow and a condition of more or less suspicion. A pulse from 45 to 50 per minute occasionally occurs when no pathologic excuse can be found, but such a slow rate is unusual. Before determining that the heart is slow it must of course be carefully examined to determine if there are beats which are not transmitted to the wrist; also whether a slow radical rate is not due to intermittency or a heart block. Auricular fibrillation, while generally causing a rapid pulse (though by no means all beats are transmitted to the peripheral arteries), may cause a slow pulse because some of the contractions of the heart are not transmitted.

"While any pulse rate below 50 should be considered abnormal and more or less pathologic, still a pulse rate no lower than 60 may be very abnormal for the individual. For athletes and those who work hard physically a slow pulse is normal. Such hearts are often not even normally stimulated by high fever, so that the pulse is unusually slow considering the patient's temperature, unless inflammation of the heart has occurred." [92: 178-79]

## DISCUSSION

As the supplementary studies are used in formulating conclusions, an understanding of the conditions under which these studies were made is important. These conditions are indicated in the following paragraphs.

*Schneider-Truesdell*

This study deals primarily with 2,000 aviators. In order to have a check on these, 200 additional unselected cases were compared with the large group. In addition, a study was made of two small groups of 144 and 204 men, judged by clinicians at the time of examination to be physically well and fit. The two groups compared were, therefore: individuals in good health, and unselected individuals. The unselected group, being composed of aviators in active training, is, as compared with the general population, a select group as to health, for individuals with serious limiting defects are excluded. The good condition group, being composed of aviators judged to be in superior physical condition, is a highly selected group.

In general composition, these two groups are quite comparable to the two groups of the primary study. In the latter study, the subjects were all active men, engaged in the usual pursuits of life, who voluntarily applied for admission to a physical education program. These men, as compared to the total population, also constitute a select group for many severe pathological conditions are excluded. Likewise, the good condition group of the primary study is a very select group, for it consisted of men considered to be in superior health.

Although the control groups in both studies are the same, i.e., individuals in good or excellent condition, the experimental groups differed, being unselected cases in the Schneider-Truesdell Study and not in good condition cases in the primary study. This difference is, however, immaterial when comparing the ranges of these groups, for in the Schneider-Truesdell Study the range for unselected cases is the same as the range for not in good condition cases. This can be demonstrated as follows:

The Schneider-Truesdell experimental group (range 51-147), being composed of unselected individuals, includes both individuals in good condition and individuals not in good condition. It is known from the data of the good condition group that the ranges for the good condition cases are 60-90 and 63-111 pulse beats per minute. It is, therefore, obvious that the extreme rates which determine the unselected range, i.e., 51 and 147 beats per minute, are for individuals not in good condition. The unselected range and the not in good condition range are, therefore, the same. Or again, if the good condition cases are removed from the unselected group, the group then consists of "not in good condition" cases. The range is, however, not affected, as the good condition range is less than, and is included within, the unselected range.

*Osborne*

The groups studied by Osborne were unselected high school pupils. Children with serious limiting defects would be excluded from this group.

*Boas and Goldschmidt; Vierordt*

The data of these studies are from clinical studies of patients.

*Bramwell and Ellis*

In this study, which deals with Olympic athletes, most of the men were examined during the ten days preceding the various contests.

The range of health in the total population may be considered to vary from severe illness to superior physical condition. No single study covers this entire range. In citing studies, an attempt has been made to select data that, collectively, would be representative of the entire range of health. In part this has been accomplished. The Schneider-Truesdell data deal with a group highly selected with regard to health (aviators in active training); the primary study deals with a somewhat less highly selected group (civilians engaged in the ordinary pursuits of life); the Osborne study with a similar selection (school children); the Boas-Goldschmidt and Vierordt studies deal with severe pathological conditions; and the Bramwell-Ellis data are cited as being representative of a particular type of individual (the highly trained athlete).

EVALUATION OF DATA

In the primary study, as shown in Table 4, there is little difference between the measures of central tendency of the two groups because the median and mean of the good condition group are only slightly less than the corresponding measures in the group composed of individuals not in good condition, and these differences are not statistically reliable.

The distinguishing difference between the two groups is found in the measures of variability. The group in good condition is less variable than the other group, and reliably so, the difference between the standard deviations being 2.42 times as large as its

standard error. The greater variability of the not in good condition group is also shown in the ranges. The range for this group is from 53 to 124 pulse beats per minute, or 71. This range is almost twice that found for the good condition group, being from 61 to 100 per minute, or 39.

The data for supplementary studies, presented in Table 5, show that the ranges of individuals in good condition (Table 5-A) are narrower than the ranges for individuals not in good condition (Table 5-B and C). In the second good condition group of 204 cases the range is practically identical with that of the good condition cases of the primary study. In the first good condition group of 144 cases the upper extremity of the range exceeds that of the primary study.

In none of the three good condition studies are rates found below 60 pulse beats per minute, and rates above 100 beats per minute are reported in only one of the three. In the three combined good condition groups there are 424 individuals. Four hundred and nineteen, or 99 per cent, had vertical pulse rates less than 100 beats per minute; five, or 1 per cent, had higher rates. There is, however, one exception to the statement that vertical pulse rates below 60 beats per minute are not found in individuals in good condition. As shown in Table 5-D, vertical pulse rates below 60 beats per minute are found in athletes.

Both extremely high and extremely low vertical pulse rates are found in individuals not in good condition. In the primary study, the rates distinctive of individuals not in good condition were those above 100 and below 61 beats per minute. In all data combined, the distinctive rates are those above 100 and below 60, with the previously noted exceptions of a few good condition cases with rates higher than 100 beats per minute, and of the slow rates found in athletes.

The rates given in Table 5-C show that certain pathological conditions, particularly myocarditis, Graves' disease, neurocirculatory asthenia, and auricular fibrillation, are accompanied by a rapid pulse—usually in excess of 100 beats per minute. Certain other pathological conditions are associated with a slow pulse. In runners, as shown in Table 5-D, the pulse is often so infrequent

that the rate would be considered very questionable in other individuals.

Investigators concur in the opinion that both the rapid pulse and the slow pulse are recognized indices of questionable physical condition.

It was necessary to consider the *influence of age* upon the pulse rate as the proposed test is intended for males of twelve years and older—a wide range. The influence of age has been frequently studied, and it is generally recognized [61: 620] that the pulse rate is highest at birth, declines with maturity, reaches a minimum during later adult life, and slightly increases in extreme age. At birth, the average pulse rate is 140 beats per minute, nearly twice the normal adult rate. During the early years of life, the pulse rate rapidly declines until at twelve years of age the average rate is but 20 per cent above the adult rate. At birth and in infancy the influence of age is a material factor in determining the pulse rate. Beyond infancy this influence becomes less important, for not only does it diminish, but other factors arise which also influence the pulse rate.[6]

In the primary group, in which the age range was from twelve to sixty-four years, the correlation between age and the frequency of the vertical pulse rate was $r = .0064$ (Table 4). The Schneider-Truesdell and Osborne studies (Table 5-A and B) also give evidence that age is of little, if any, importance in determining the vertical pulse rate range after childhood. In the Schneider-Truesdell group of 2,000 men between eighteen and forty-two years of age, the vertical pulse rate range was from 51 to 147 beats per minute. Practically the same range, 50 to 148 beats per minute, was reported by Osborne for the pubescents,[7] a much younger group. These data have been interpreted as indicating that age is not a material factor in the determination of the range of pulse frequency, within the age range tested or within the age range for which this study is designed.

[6] See page 55 for a discussion of the factors which influence the pulse rate.

[7] In this study, the stage of development was determined by the character of the hair on the pubes. Pubescents were those with a fine growth of hair. This usually occurs in the early teens.

### RATES WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *Rate Per Minute* |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that rate is normal. | 61–100 [8] |
| *Questionable Reactions* | |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition. | 60 or less<br>101 or more |
| Found in pathological individuals. | |
| Investigators are in agreement that the rate is a pathological symptom. | |

*Critical Scores.* In the vertical pulse rate there are two questionable condition ranges, namely, excessively rapid rates and excessively slow rates, and two critical scores where these excessive rates begin. The criteria, when applied to the data of this study, established these scores at 60 and 100 beats per minute. These points or scores are not necessarily the most desirable for the final scaling of the item, and several other possibilities were considered. Since the problems involved are common to all of the seven selected items, a discussion of this point will be reserved until all data have been presented.[9]

### SUMMARY AND CONCLUSION

The pulse rate has been studied and its diagnostic value recognized for the past two thousand years. In this study, the vertical

[8] These conclusions, as previously mentioned, were based upon (1) a primary study, (2) supplementary studies, and (3) expert opinion. Only those ranges were considered significant in which there was general agreement in all data. Complete mathematical agreement among the ranges of the several studies was not always found. Where disagreement occurred, the data were evaluated before conclusions were made. The basis for these conclusions is given in some detail.

[9] The discussion of possible methods for locating critical scores is given on pages 93-96.



pulse rates of individuals in good condition and other individuals were compared. Rates in pathological individuals were also studied, and the opinions of investigators were reviewed. All data and opinions are in agreement that:

1. Both rapid and slow pulse rates are found very infrequently in individuals who *are* in good health.
2. Both rapid and slow pulse rates are found in individuals who are *not* in good health.
3. Both the rapid and the slow pulse are indications of questionable physical condition.

The data indicate that:

1. Vertical pulse rates of 101 or more beats per minute should be considered *rapid*.
2. Vertical pulse rates of 60 or fewer beats per minute should be considered *slow*.

### *Item 2: Postural Pulse Rate Change* (*Difference Between Horizontal and Vertical Pulse Rates*)

#### GENERAL STATEMENT

The postural pulse rate change is one of the traditional indices of physical condition. Its physiology was worked out by Erlanger and Hooker [44] in 1904. Since then it has been developed by McCurdy [72: 421-32], Crampton [35], Sewall [126], Schneider [117], Addis [1], and others. Essentially, it is merely a method of measuring the ability of the cardiovascular system to overcome the effect of gravity upon the blood bed when the subject rises from the horizontal to the vertical position. An additional element enters into the postural pulse rate change, namely, the extra expenditure of energy required to maintain the vertical posture in contrast with the horizontal. [15] These two factors, increased effect of gravity and increased expenditure of energy, produce the differences between the vertical and the horizontal pulse rates—the factor which is measured in postural pulse rate change.

**DATA**

Three types of data are presented. In Table 6, results of the investigations of this study are presented. The results of other investigators are given in Table 7. Clinical evidence is given under the heading "Additional Data."

TABLE 6

POSTURAL PULSE RATE CHANGE—PRIMARY STUDY

| Postural Pulse Rate Change (Minutes) | Number of Cases: In Good or Excellent Condition | Number of Cases: Not in Good or Excellent Condition | Per Cent of Group: In Good or Excellent Condition | Per Cent of Group: Not in Good or Excellent Condition |
|---|---|---|---|---|
| 36 | | 1 | | .6 |
| 34 | | | | |
| 32 | | | | |
| 30 | | | | |
| 28 | | 1 | | .6 |
| 26 | | | | |
| 24 | | 3 | | 1.7 |
| 22 | | | | |
| 20 | | 7 | | 4.0 |
| 18 | | | | |
| 16 | | 7 | | 4.0 |
| 14 | 1 | 2 | 3.1 | 1.2 |
| 12 | 3 | 12 | 9.4 | 6.9 |
| 10 | 1 | 11 | 3.1 | 6.3 |
| 8 | 2 | 17 | 6.2 | 9.8 |
| 6 | 5 | 24 | 15.7 | 13.8 |
| 4 | 11 | 35 | 34.4 | 20.0 |
| 2 | 5 | 20 | 15.7 | 11.5 |
| 0 | 1 | 26 | 3.1 | 14.9 |
| −2 | | 4 | | 2.3 |
| −4 | 1 | 2 | 3.1 | 1.2 |
| −6 | 1 | | 3.1 | |
| −8 | | 1 | | .6 |
| −10 | 1 | 1 | 3.1 | .6 |
| Total | 32 | 174 | 100.0 | 100.0 |
| Range | −10 to +14 | −10 to +36 | | |

| | | | Difference | Standard Error of Difference |
|---|---|---|---|---|
| Mode | +4 | +4 | | |
| Median | +4.3 | +4.9 | .6 | 1.25 |
| Mean | +4.375 | +6.31 | 1.93 | 1.23 |
| Standard Deviation | 4.91 | +6.58 | 1.67 | .88 |

TABLE 7

POSTURAL PULSE RATE CHANGE—SUPPLEMENTARY DATA

| Investigator | N | Sex | Age Group | Description of Subjects or Disease | Postural Pulse Rate Change (Minutes) | |
|---|---|---|---|---|---|---|
| | | | | | Range | Mean |
| A. Schneider and Truesdell [121: 434–36] | 204 | M | Young adults | Good condition | 0 to +33 | +12.5 |
| | 144 | M | Young adults | Good condition | −3 to +36 | +13.8 |
| B. Schneider and Truesdell [121: 434–36] | 2,000 | M | Young adults | Unselected | −15 to +57 | +17.9 |
| | 200 | M | Young adults | Unselected | −3 to +36 | +14.9 |
| Falconer [45] | —* | — | — | Unselected | +1 to +13 | +6 |
| Graves [55] | — | — | — | Unselected | +6 to +15 | — |
| Schapiro [116] | 50 | M | Young adults | Unselected | +2 to +34 | +14 |
| Vierordt [138] | — | — | — | Unselected | — | +12 |
| Kahn [62] | 233 | M | — | Unselected | 0 to +28 | +16 |
| Parkinson [94] | — | M | Young adults | Normals | — | +10 |
| C. Parkinson [94] | — | M | Young adults | Soldier's Heart—Negative physical examination | — | +16 |
| Crampton [36] | — | — | — | Wearied subjects | — | As much as 44 beats |

* Dash (—) indicates data not given.

## ADDITIONAL DATA

There is also considerable clinical evidence that a condition known variously as neurogenic sinus tachycardia, neurocirculatory asthenia, soldier's heart, and effort syndrome is characterized by a marked tachycardia or rapid heart upon slight exertion. Boas and Goldschmidt [17: 131-32] give several objective studies of this condition in which the ranges are as follows: 65 (during sleep) increased to 100 to 140 (during waking hours); 52 (during sleep) increased to 109 (while sitting reading). Auricular

fibrillation may also cause marked increase in pulse rate upon slight exercise. Boas and Goldschmidt [17: 133] report for a man with this condition, "A simple conversation suffices to produce an acceleration of 18 beats; walking provokes a rise of 73 beats; eating a rise of 8 beats a minute; and a short nap reduces the rate by 16 beats a minute."

### OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning postural pulse rate change follows.

*Meylan* [81: 444]

An increase of not more than 16 beats is a favorable sign.

*Turner* [136]

Best standing reaction is an increase of 10 beats from a reclining rate of from 50 to 60.

*Crampton* [37]

Little or no increase in pulse rate is indicative of good physical condition.

*Geigel* [53]

Variation in excess of 30 indicates weakened heart condition.

*Schneider and Truesdell* [121: 440]

"Physically fit men show a smaller difference between reclining and standing than do men generally."

### DISCUSSION

Although the results indicate in a general way that smaller postural pulse rate changes are found in individuals in good condition than in other individuals, inasmuch as the data are not in agreement it is difficult to define what constitutes a normal or a questionable reaction.

In the primary study (Table 6), the range, median, mean, and standard deviation of the good condition group are less than the corresponding measures in the other groups. The differences between the medians and means, however, are not statistically reliable. The difference between the standard deviations is reliable at the .05 level.

In the supplementary data (Table 7), the ranges and means of the two Schneider-Truesdell good condition groups are less than the corresponding measures in their large unselected group of 2,000 cases. However, the range of the smaller good condition group (144 cases) is identical with the range of the smaller unselected group (200 cases). Furthermore, when the not in good condition group of the primary study is compared with the Schneider-Truesdell smaller good condition group there is little difference in the ranges, and the mean of the Schneider-Truesdell good condition group is twice as large as the mean of the not in good condition group of the primary study. This is the reverse of the situation which would be found if large postural pulse rate changes were in all cases associated with poor physical condition.

The other ranges reported in Table 7-B also are not in agreement. The ranges reported by Falconer and Graves agree with the good condition group of the primary study—within sixteen beats a minute; the studies by Schapiro and Kahn agree with the Schneider-Truesdell good condition range—upper limit approximately thirty beats a minute. The evidence from the study of pathological cases (Table 7-C) is also inconclusive. Although the average pulse rate change[10] of patients is larger than for controls—healthy persons—(Parkinson's study, Table 7-B and C), the average for patients is only slightly higher than the averages of the Schneider-Truesdell good condition groups. There is, however, agreement among the investigators cited that a small increase is a favorable sign, and a large increase indicates poor condition.

Within each of the several studies, with the previously noted exception of the Schneider-Truesdell smaller unselected group, the ranges of the good condition cases are narrower than those for other individuals. However, when the range in one study is compared with the range in another study, it is difficult to form any definite conclusion, as the good condition range in some studies approximates the not in good condition range in other studies. It is probable that the lack of consistency in the data

[10] In this study the range is not given.

is due, at least in part, to variations in methods of administration used in the several studies.

Negative changes (horizontal pulse rate greater than vertical rate) were found in both primary groups, and in three of the four Schneider-Truesdell groups. Eight, or 5 per cent, of the not in good condition group of this study, and three, or 9 per cent, of the good condition group had negative changes. In the Schneider-Truesdell group, negative changes were less frequent, being .9 per cent, unselected group (2,000 cases); 1 per cent, unselected cases (200); 0 per cent, good condition cases (204); 1.4 per cent, good condition cases (144). No clear indication of the association of negative change with physical condition can be seen in these data. The slightly greater occurrence of negative changes in the good condition group and in one of the Schneider-Truesdell good condition groups suggests one relationship; the absence of these changes in the second Schneider-Truesdell group suggests another and different relationship. In all the studies the number of cases with negative changes was small, and the difference in percentages for the different groups was not conclusive. Furthermore, no conclusions could be found among investigators concerning the significance of these negative changes. Thus, negative postural pulse rate changes failed to satisfy two of the criteria of this study for rates which are indicative of questionable physical condition in that (1) they were found in individuals known to be in good condition; and (2) no agreement concerning their significance could be found among investigators.

### RATES WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *Rate Per Minute* *Primary Studies* | *Supplementary Studies* |
|---|---|---|
| *Normal Reactions* | | |
| Found in individuals in good or excellent condition. | —10 to +14 | —3 to +36 |
| Investigators are in agreement that rate is normal. | | Up to 16 beats |

| *Criteria* | *Rate Per Minute* *Primary Studies* | *Supplementary Studies* |
|---|---|---|
| *Questionable Reactions* | | |
| Not found in individuals in good or excellent condition. | Below —10<br>Above 14 | Below —3<br>Above 36 |
| Found in pathological individuals. | | 16 (mean) |
| Investigators are in agreement that the rate is a pathological symptom. | | Above 16 |

Postural pulse rate changes up to and including 14 beats per minute satisfy the criteria for normal reactions in that they are found in individuals in good or excellent condition and investigators are in agreement that the rate is normal.

Postural pulse rate changes above 36 beats a minute satisfy the criteria for questionable rates in that they are not found in individuals known to be in good condition and investigators are in agreement that such rates are pathological symptoms.

The significance of negative postural pulse rate changes and positive changes between 15 and 36 beats per minute is not clear, inasmuch as the evidence is not in agreement.

## SUMMARY AND CONCLUSION

The postural pulse rate change has long been studied and frequently used as a measure of physical condition. The data indicate that in individuals unselected as to health there is considerable variation in this measure, and that the variation is often less in individuals selected for good health than in other individuals. The evidence, however, is not in agreement concerning what constitutes normal and questionable reactions beyond indicating that rates below 15 beats a minute may be considered normal reactions, and rates of 37 beats or more a minute may be considered questionable reactions. No conclusion could be reached regarding the significance of negative changes and of rates between 16 and 36 beats per minute. For the purposes of this study these rates were therefore classified as of questionable significance.

### *Item 3: Increase in Pulse Rate After Exercise (Pulse Rate Immediately After Exercise)*

GENERAL STATEMENT

An increase in the frequency of the heartbeats is one of the adaptations of the body to exercise. Muscular activity increases the oxygen need of the tissues and the end products of metabolism, chief of which is carbonic acid. In strenuous exercise each litre of blood must transport from tissues to lungs as much as 600 cc. of carbon dioxide per minute and four litres of oxygen from the lungs to the tissues. The intake of oxygen and the removal of carbonic acid are accomplished in the lungs during respiration. One of the conditioning factors in this process is the volume of blood passed through the alveolar processes of the lung. This, in turn, is dependent upon the minute-volume of the heart, which is determined by measuring the volume of the heart per beat and multiplying by the pulse rate per minute. Hence, the more frequent the heart rate the greater the minute-volume, other things being equal.

However, other factors are not equal, for, as Henderson, Haggard, and Dolley [59] have shown, "When a man out of training exerts himself so that the pulse rate is doubled, his circulation is usually merely doubled also. When the athlete's pulse rate is doubled, his circulation often undergoes an increase to three or more times the resting value. Thus fundamentally the doubling of the pulse increases the difference between the two classes during exertion. Twice a resting pulse of 60 is 120 beats per minute; twice one of 80 is 160; twice one of 90 is 180. A pulse of 120 during work, such as an athlete may have, is associated with no sense of strain; but one of 180, as in a man out of training, is near the extreme upper limit of efficient work for a heart of the size of that of man. At rates above 180 the efficiency decreases progressively, for the diastoles then become too brief to allow the ventricles to relax and refill. It is the relatively slow full pulse of the athlete which enables his heart to supply the blood stream and transportation of oxygen for a four mile boat race or a Marathon Run."

**DATA**

The exercise used in securing the data presented in Table 8 was a four-count front leaning rest, executed from standing position, repeated four times at maximum speed. The reasons for the selection of this exercise are outlined on page 45; the method of administration is given in Chapter V.

TABLE 8

INCREASE IN PULSE RATE AFTER EXERCISE—PRIMARY STUDY

| Increase in Pulse Frequency (Minutes) | Number of Cases | | Per Cent of Group | |
|---|---|---|---|---|
| | In Good or Excellent Condition | Not in Good or Excellent Condition | In Good or Excellent Condition | Not in Good or Excellent Condition |
| 80 | | 1 | | .5 |
| 76 | | | | |
| 72 | | | | |
| 68 | | | | |
| 64 | | 3 | | 1.4 |
| 60 | | 5 | | 2.3 |
| 56 | 1 | 4 | 2.6 | 1.8 |
| 52 | 1 | 6 | 2.6 | 2.7 |
| 48 | | 16 | | 7.3 |
| 44 | 5 | 18 | 13.2 | 8.3 |
| 40 | 7 | 37 | 18.4 | 17.0 |
| 36 | 5 | 27 | 13.2 | 12.4 |
| 32 | 11 | 38 | 29.0 | 17.4 |
| 28 | 1 | 21 | 2.6 | 9.6 |
| 24 | 1 | 13 | 2.6 | 6.0 |
| 20 | 2 | 19 | 5.3 | 8.7 |
| 16 | 2 | 8 | 5.3 | 3.7 |
| 12 | 1 | 2 | 2.6 | .9 |
| 8 | 1 | | 2.6 | |
| Total | 38 | 218 | 100.0 | 100.0 |
| Range | 8 to 56 | 12 to 80 | | |
| | | | Difference | Standard Error of Difference |
| Mode | 32. | 32. | | |
| Median | 34. | 35.18 | 1.18 | 2.34 |
| Mean | 33.79 | 35.63 | 1.84 | 2.20 |
| Standard Deviation | 10.20 | 12.80 | 2.60 | 1.50 |

### OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning increase in pulse rate after exercise follows.

*Flack and Bowdler* [46]

The chair-stepping exercise (stepping on chair eighteen inches high, five times in fifteen seconds) was used by these authors, who concluded that an increase in rate of more than twenty-five beats per minute was an unfavorable health sign.

*Cotton, Lewis, and Rapport* [33: 277-78]

These three authors studied the aftereffects of exercise in cases of irritable heart, and concluded, "It is clear that if we choose a given amount of work as a stimulus and apply this stimulus to healthy controls and to our patients, the latter react to this stimulus in an exaggerated fashion. The pulse rate rises much higher than in controls. . . ."

*Meylan* [81: 444]

The effects of exercise upon the heart rate of college students were studied by Meylan, who concluded that (1) an increase in pulse rate of less than 100 per cent after hopping 100 feet is a favorable sign; (2) an increase in pulse rate greater than 100 per cent is an unfavorable sign.

*Meakins and Gunson* [79]

These investigators report for cases of irritable heart that, "The increase of pulse rate immediately after exercise is relatively more marked than in normal cases. . . ."

### DISCUSSION

Here again, in the primary study, there is little difference between the measures of central tendency (modes, medians, and means) of the two groups, and these differences are not statistically reliable.

The measures of variability, the range and standard deviation, are larger in the not in good condition group. The good condition range is 48 pulse beats per minute, while that of the not in good condition group is 68 beats. The difference between the standard deviations is 1.7 times its standard error, and is, therefore, reliable at the .09 level. In a normal distribution there are 91 chances in 100 that such a difference is larger than zero. In all

of the four studies of athletes and non-athletes (Table 9-A) the increases in pulse rate after exercise of the athletes were less. Also in the studies of pathological cases (Table 9-B) the increases in pulse rate after exercise of the "normals" were less than those of the patients.

TABLE 9

INCREASE IN PULSE RATE AFTER EXERCISE—SUPPLEMENTARY STUDIES

| Investigator | Exercise | Pulse Rates: At Rest | | Pulse Rates: Increase After Exercise | |
|---|---|---|---|---|---|
| | | *Athletes* | *Non-Athletes* | *Athletes* | *Non-Athletes* |
| A. Henderson, Haggard, and Dolley [59] | Bicycle ergometer—120 turns a minute, 960 kilograms of work per minute | 66 | 81 | 68 | 84 |
| Hartwell and Tweedy [57] | Stair climbing—height 37 feet, 3 inches; time 45 minutes | 76 | 78 | 24 | 32 |
| Pembrey and Todd [96] | A brief period of vigorous exercise | 64 | 68 | 68 | 84 |
| | | 56 | 82 | 64 | 78 |
| | | 60 | 68 | 68 | 84 |
| Bainbridge [5: 67] | Bicycle ergometer—metabolic rate, 2 litres of oxygen a minute | 58 | 89 | 60 | 71 |
| | | *Normals* | *Patients** | *Normals* | *Patients** |
| B. White [146] | Stair climbing—50 steps, each 6¼ inches high, in one minute | | | (Average) 19 | (Average) 28 |
| Cotton, Lewis, and Rapport [33: 278] | 30 lifts—20 lb. bells, in 60 seconds | 72 | 81 | 55 | 77 |
| | | 95 | 77 | 35 | 69 |
| | Normals lifted 20 lb. bells 20 times in 40 seconds; patients 20 times in 60 seconds | 74 | 83 | 44 | 71 |
| | | 98 | 114 | 25 | 48 |
| | | 71 | 101 | 49 | 56 |
| Parkinson [94] | Walking up 25 steps (Averages) | 82 | 93 | 23 | 38 |

* Effort syndrome and irritable heart cases.



Pulse rate increases greater than 59 beats a minute were not found in the 38 good condition cases of the present study. There were, however, few good condition cases with increases larger than 47 beats a minute. As shown in Table 8, the good condition distribution ends practically at 47 beats, for there are no cases in the next higher frequency and only one case in each of the two following frequencies.

There is general agreement among students of pulse rates that an exaggerated increase after exercise is an unfavorable sign. The opinions cited express this agreement.

### REACTIONS WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *Rate per Minute* |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that reaction is normal. | Moderate increase—up to, and including, 56 beats after test exercise |
| *Questionable Reactions* | |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition.<br>Found in pathological individuals.<br>Investigators are in agreement that the reaction is a pathological symptom. | Exaggerated increase—60 or more beats after test exercise |

### SUMMARY AND CONCLUSION

The increase in pulse rate after exercise is an important adaptation of the body to muscular exercise, and has long been recognized as an index of physical condition. The pulse rate increases, after the standard exercise, of individuals (1) in good condition and (2) not in good condition were compared. The increases of individuals not in good condition were larger than those of individuals in good or excellent health.

Data from numerous studies of the increase in pulse rate after

exercise in both normal and pathological subjects were reviewed, and the opinions of authorities were investigated. All data and opinions were in agreement with the findings of the present study, namely, that an exaggerated increase in pulse rate after exercise is (1) not found in good condition cases; (2) found in individuals who are not in good physical condition; and (3) an indication of questionable physical condition.

The rates which satisfy the criteria are normal rates 8-56 beats a minute, and questionable rates 57-80 beats a minute.

### *Item 4: Pulse Rate Reaction After Exercise* (*The Return to Normal of the Pulse Rate After Exercise*)

#### GENERAL STATEMENT

It is a common experience that individuals in good physical condition recover from the effects of exercise more quickly than other individuals. This better adaptation to exercise of the trained man is accomplished by (1) an increase in the size (i.e., the muscular tissue) of the heart, which enables it not only to develop more energy per beat, but also to empty itself more completely at each beat when the exercise becomes so severe, and the venous inflow so large that the heart dilates to its physiological limit during diastole [5: 185]; (2) an increase in the red corpuscles and hemoglobin value of the blood [120]; (3) an increase in the mechanical efficiency with which the work is performed [14]; and (4) a smaller consumption of oxygen and a smaller output of carbonic acid. [5: 187]

#### DATA

The exercise used to secure the pulse rates given in Tables 10 and 11 was the four-count front leaning rest, executed from standing position, four times at maximum speed.

#### OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning pulse rate reaction after exercise follows.

*Meakins and Gunson* [79]

"The patients in whom the pulse rate did not return to normal within

a short period of time performed the simplest exercises with difficulty.

"Acute infections occurring in individuals with 'irritable heart' accentuate the symptoms, produce a conspicuous increase in the pulse rate before and after exercise, and cause a pronounced delay in the return of the pulse to normal."

*Meylan* [81: 444]

Recovery in one minute of more than 80 per cent of the pulse rate increase after hopping 100 feet, a favorable sign; recovery of less than 80 per cent, an unfavorable sign.

*Cotton, Lewis, and Rapport* [33: 269]

"It is clear that if we choose a given amount of work as a stimulus and apply this stimulus to healthy controls and to our patients the latter react to this stimulus in an exaggerated fashion. *The pulse rate rises much higher than in controls, and the high rate is longer sustained,* . . ." [Italics are mine.]

*Cook and Pembrey* [31]

"The return of the pulse to its rate during rest is of considerable importance. In the well trained man there is a rapid recovery and a tendency for the rate of the pulse to fall below its original value during rest; in the untrained man the rate remains high and often irregular for some time."

### DISCUSSION

In the primary study (Table 10), the return to normal of the good condition group is quicker than that of the other group. All of the good condition group had returns within 120 seconds. Of the not in good condition group 7.8 per cent required more than two minutes for the pulse rate to return to normal.

The quicker return of the pulse rate after exercise in the physically fit is also shown by the data in Table 11-A. In the group selected for superior physical condition, the pulse rate of practically all had returned to the resting rate within two minutes. In the two groups of individuals unselected as to physical condition the returns were less prompt: 22.6 per cent of one group and 36.9 per cent of the other group had pulse rates higher than the resting rate of two minutes after the completion of the exercise. These differences are striking, in view of the fact that the subjects of the unselected group were soldiers who had been passed for active service by examining physicians.

TABLE 10

RETURN TO NORMAL OF THE PULSE RATE AFTER EXERCISE—PRIMARY STUDY

| Seconds Required for Pulse Rate to Return to Normal | Number of Cases: In Good or Excellent Condition | Number of Cases: Not in Good or Excellent Condition | Per Cent of Group: In Good or Excellent Condition | Per Cent of Group: Not in Good or Excellent Condition |
|---|---|---|---|---|
| 180 | | 2 | | .9 |
| 165 | | 2 | | .9 |
| 150 | | 6 | | 2.8 |
| 135 | | 7 | | 3.2 |
| 120 | 13 | 42 | 33.3 | 19.3 |
| 105 | | 9 | | 4.1 |
| 90 | 4 | 28 | 10.3 | 12.8 |
| 75 | 2 | 31 | 5.1 | 14.2 |
| 60 | 15 | 66 | 38.4 | 30.3 |
| 45 | 1 | 10 | 2.6 | 4.6 |
| 30 | 4 | 15 | 10.3 | 6.9 |
| Total | 39 | 218 | 100.0 | 100.0 |
| Range | 30 to 120 | 30 to 180 | | |
| | | | Difference | Standard Error of Difference |
| Mode | 60. | 60. | | |
| Median | 67.0 | 76.2 | 9.2 | 2.43 |
| Mean | 80.38 | 83.74 | 3.36 | 5.70 |
| Standard Deviation | 31.43 | 32.85 | 1.42 | 4.03 |

The two studies of pathological cases (Table 11-B) disclose an interesting fact. In the first study (Meakins and Gunson), the pulse rate return in patients who did not suffer distress after exertion compared favorably with that of normals; in patients who had suffered distress after exertion the return was less prompt. A similar difference in types of patients is also indicated by the data of the second study (Cotton, Lewis, and Rapport). In the first comparison (two best patients with three controls) the returns to normal of the controls and of the patients are equal. In the second comparison (three patients and three controls), although the exercise performed by the patients was less severe, the returns in two instances were much slower. In the first study the exercise consisted of 30 lifts (20 pound bells) in 60 seconds, while in the second study the exercise consisted of 20 lifts.

TABLE 11

RETURN TO NORMAL OF PULSE RATE AFTER EXERCISE—SUPPLEMENTARY STUDIES

| Investigator | Number of Cases | Group | Per Cent of Group With Rate Above Normal at End of Two Minutes After Exercise* |
|---|---|---|---|
| A. Schneider and Truesdell [121: 443-44] | 204 | Good condition cases | .98 |
| | 2,000 | Unselected cases | 22.6 |
| | 217 | Unselected cases | 36.9 |
| | | | **Time in Seconds for Pulse Rate to Return to Normal After Exercise** |
| B. Meakins and Gunson [79] | | Normals | Less than 60† |
| | | Patients‡ without symptoms of distress after exertion | Less than 60 |
| | | Patients with symptoms of distress after exertion | More than 60 |
| Cotton, Lewis, and Rapport [33: 269] | | Normals | |
| | | C. | 280§ |
| | | L. | 100 |
| | | R. | 80 |
| | | Best Patients‡ | 280 |
| | | | 80 |
| | | Normals | |
| | | C. | 160** |
| | | L. | 80 |
| | | R. | 80 |
| | | Patients‡ | |
| | | CL. | 80†† |
| | | HI. | 260 |
| | | HE. | 260 |

* The exercise used was stepping up on a chair 18 inches high, five times in 15 seconds.
† Exercise consisted of a walk of 75 paces at ordinary quick time, terminating with climbing 27 steps (18 feet).
‡ Irritable heart cases.
§ Exercise consisted of 30 lifts (20 lb. bells) in 60 seconds.
** Exercise consisted of 20 lifts (20 lb. bells) in 40 seconds.
†† Exercise consisted of 20 lifts (20 lb. bells) in 60 seconds.

Meylan, and Cook and Pembrey investigated the speed of the pulse rate return in physically fit individuals as compared with that in individuals less fit. Their opinion, which is substantiated by numerous other investigators, is that the return is more prompt



in the physically fit. Workers who have studied the relative speed of recovery in patients and normals (Cotton, Lewis, and Rapport; Meakins and Gunson) agree that in patients with irritable heart who experience distress after exertion, the return is less prompt than in normals.

## REACTIONS WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *Time for Pulse Rate to Return to Normal* |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that reaction is normal. | Prompt return—up to, and including, 120 seconds after test exercise. |
| *Questionable Reactions* | |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition. Found in pathological individuals. Investigators are in agreement that the reaction is a pathological symptom. | Delayed return—121 or more seconds after test exercise. |

## SUMMARY AND CONCLUSION

The time required for the return of the pulse rate to normal after exercise is a recognized measure of physical condition, for it is a common experience that athletes and others in good physical condition recover quickly from the effects of physical exertion. There are also numerous studies of the physiology of exercise which substantiate this conclusion.

Objective studies of the pulse rate return in individuals selected for physical fitness and in other individuals show that the return of the pulse rate after exercise to its previous resting rate is more prompt in physically fit individuals.

Studies of the pulse rate return in patients with irritable heart show that when the condition causes distress upon exertion, the

return is less prompt. Acute infections also are associated with a pronounced delay in the return.

Investigators of the pulse rate return after exercise are in agreement that a quick recovery is a favorable indication, and a slow recovery is an unfavorable indication.

After our standard exercise all of the pulse rates of the good condition group returned to normal within 120 seconds; in 7.8 per cent of individuals not in good condition the pulse rates did not return to normal within that time. Pulse rate returns of 120 seconds or less satisfied the criteria for normal reactions. Pulse rate returns of 121 or more seconds satisfied the criteria for questionable reactions.

### *Item 5: Breathlessness After Activity*

#### GENERAL STATEMENT

The need for oxygen and the output of carbon dioxide are increased during exercise, for metabolism is accelerated. These increased demands are met by several adjustments of the respiratory system, one of which is an increase in the minute-volume of air breathed. It has been shown [119] that there is a linear relationship between the minute-volume of respiration and the amount of work accomplished as long as the work is moderate. When the work becomes excessive, lactic acid enters the blood in considerable amount and breathing becomes excessive. It is, therefore, possible to use the onset of breathlessness as an indication of excessive activity, and the amount of work that can be performed without breathlessness as a test of physical condition.

#### DATA

The results of the primary study of breathlessness after executing the standard test exercise are presented in Table 12. Results of other studies of breathlessness after activity are presented in Table 13. These latter studies deal with normals, athletes, nonathletes, obese persons, convalescents, and patients afflicted with compensated cardiac disorders, anemia, neurocirculatory asthenia, and psychoneurosis.

TABLE 12

BREATHLESSNESS AFTER ACTIVITY—PRIMARY STUDY

| Group | N | Not Breathless After Exercise | | Breathless* After Exercise† | |
|---|---|---|---|---|---|
| | | Number | Per Cent | Number | Per Cent |
| In good or excellent condition... | 39 | 39 | 100.0 | | |
| Not in good or excellent condition | 219 | 201 | 91.8 | 18 | 8.2 |

* Breathlessness was judged to be present when there was distinct elevation of the chest wall on inspiration, and forced expiration. See page 102 for further details.

† The exercise used was the four-count front leaning rest, executed four times at maximum speed.

TABLE 13

BREATHLESSNESS AFTER ACTIVITY—SUPPLEMENTARY STUDIES

| Investigator | Exercise | Group | N | Number | | Per Cent |
|---|---|---|---|---|---|---|
| | | | | *With Dyspnea After Exercise* | | |
| Mudd and Means [87] | Walking 20 feet, climbing 18 steps, 7 inches high, twice in 60 seconds | Normals........ | 8 | 0 | | 0 |
| | | Obese.......... | 4 | 3 | | 75 |
| | | Compensated cardiac disorder.... | 10 | 8 | | 80 |
| | | Anemic........ | 3 | 0 | | 0 |
| | | | | *Average Respiration Rate Per Minute* | | |
| | | | | *At Rest* | *After Exercise* | *Difference* |
| Hartwell and Tweedy [57] | Running up and down stairs, 37 feet, 8 inches high, in 45 seconds | Athletic........ | 16 | 20 | 27 | 7 |
| | | Non-athletic.... | 38 | 21 | 30 | 9 |
| | | | | *Average Increase in Respiration Rates Per Minute* | | |
| White [146] | Stair climbing, 50 steps, 6¼ inches high, in one minute | Normals........ | 5 | | 2 | |
| | | Effort syndrome | 5 | | 9 | |
| | | Convalescing.... | 5 | | 5 | |
| | | Psychoneurosis.. | 5 | | 17 | |

### OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning breathlessness after activity follows.

*Vierordt* [139: 84-86]

Increased frequency of respiration occurs: (1) in fever; (2) in all conditions that are connected with pain in breathing; (3) in diseases of the bronchial tubes; (4) in all diseases of the lungs; and (5) in diseases of the heart which cause stasis of blood in the lung circulation.

*Osborne* [92: 14]

"If there is more dyspnea than normally should occur in the individual patient after walking rapidly or climbing a hill or going upstairs; if after a period of a little excitement one finds that he cannot breathe quite so deeply, or that something feels tight in his chest, the heart needs resting; . . ."

*Mackenzie* [67: 90]

"The condition which goes now under a variety of names—as soldier's heart, the irritable heart of soldiers, disordered action of the heart, effort syndrome and neuromuscular asthenia—is not peculiar to soldiers, but is of frequent occurrence in civil life. The ill health or incapacity which is present is not limited or only due to the cardiac condition, for other organs are also affected, so that the cardiac manifestations form but a part of the picture of ill health. *The main symptoms of which the soldiers complained were shortness of breath or exhaustion or palpitation easily produced on moderate effort.*" [Italics are mine.]

*Mackenzie* [67: 230]

"Breathlessness is so frequently associated with affections of the heart that its occurrence under any circumstances necessitates a consideration of the heart's condition."

*Peabody and Sturgis* [95]

"The tendency to dyspnea on exertion increases progressively as the vital capacity falls, and there is abundant evidence to indicate that the interference with pulmonary ventilation is an important factor in producing dyspnea, but, particularly in the early stages of heart disease."

### DISCUSSION

All studies point to the conclusion that individuals who are not in good or excellent condition, especially those who are obese or

afflicted with cardiac disturbances, may become breathless after short exertion.

None of the good condition group were breathless after performing the test exercise (Table 12). The ability of such individuals to perform activities of short duration without dyspnea is also shown in the studies by Mudd and Means, and by White (Table 13). In the Mudd and Means study, none of the normal group were dyspnoeic after stair climbing, an exercise approximately equal to our test exercise in the amount of work performed. In the study by White, the increase in respiration rate for the normal group was very slight.

Eighteen, or 8.2 per cent, of the experimental group in the primary study experienced breathlessness after the test exercise (Table 12). Similar results were found by Mudd and Means (Table 13), since members of both the obese group and the cardiac group had dyspnea after the exercise. The investigation by Hartwell and Tweedy (Table 13) dealt with women college students who were all apparently healthy. The increase in respiration rates of the more athletic members of the group was less than that of the non-athletic members.

The data for pathological conditions (White, Table 13), although quite limited as to the number of cases studied, show a very decided tendency for excessive breathing rate after exertion to be associated with pathological conditions. There is an increase in respiration rate of from 2¼ to 8¼ times the normal increase in the three pathological groups studied.

The occurrence of respiratory difficulties and increased frequency of respiration, with numerous diseased conditions, has long been known (Vierordt, 1891). The importance of breathlessness after slight exertion as an indication of questionable condition also has long been recognized. This is clearly shown by the quotations from Osborne, Mackenzie, and Peabody and Sturgis. The statement by Osborne indicates the diagnostic value of the early onset of dyspnea in unselected cases. The statements by Mackenzie and Peabody and Sturgis indicate the diagnostic value of early dyspnea in cardiac and pulmonary disturbances.

REACTIONS WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *State of Respiration* |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that reaction is normal. | Not breathless after the test exercise. Dyspnea ***not*** present after short exertion. |
| *Questionable Reactions* | |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition.<br>Found in pathological individuals.<br>Investigators are in agreement that the reaction is a pathological symptom. | Breathless after the test exercise. Dyspnea ***present*** after short exertion. |

SUMMARY AND CONCLUSION

The onset of breathlessness is an indication of excessive activity, and, as has been shown by numerous physiological studies, the amount of physical work that can be performed without breathlessness may be used as a test of physical condition. The presence or absence of breathlessness after the performance of the test exercise of this study was used as a test of condition.

Thirty-nine individuals known to be in good physical condition and 219 individuals not in good or excellent condition were given the test exercise, and the presence or absence of breathlessness after the exertion was noted. None of the good condition group was breathless. Eighteen, or 8.2 per cent, of the individuals not in good condition were breathless.

Reports of three investigations of respiration rates in various groups were given. The evidence from these studies is in agreement that the increase in respiration rate after exertion is less in individuals in good condition than it is in other indviduals.

The opinions of six students of respiration rates were cited. These opinions are in agreement that (1) the early onset of

breathlessness after exertion is associated with numerous pathological conditions; (2) early breathlessness is an important diagnostic sign of questionable physical condition.

It was concluded that breathlessness after performing the test exercise of this study is an indication of questionable physical condition.

### *Item 6: Limited Motor Movement*

#### GENERAL STATEMENT

There are numerous defects, particularly of nutrition and of the neuromuscular and skeletal systems that limit the possible range of physical movement. Although the exact measurement of these defects is largely a medical problem, it is necessary for the measurement of physical capacity that such limiting conditions be detected.

#### DATA

The performance of the test exercise was used as a test of limited motor movement.

TABLE 14

LIMITED MOTOR MOVEMENT

| Group | Number of Cases | Unable to Perform Test Exercise | | With Limiting Physical Defects as Shown by Medical Examination | |
|---|---|---|---|---|---|
| | | Number | Per Cent | Number | Per Cent |
| In good or excellent condition... | 39 | none | | none | |
| Not in good or excellent condition | 232 | 13 | 6 | 13 | 6 |

#### DISCUSSION

The validity of the test exercise as a measure of limited physical movement resides primarily in the nature of the movement itself, for inability to execute a deep-knee bend, support the weight of the body on the arms, extend the legs, flex the legs, and assume an

erect position—the movement required in the standard exercise—is prima-facie evidence of limited motor function. A simple test of this type is not, and is not intended to be, a comprehensive measure of physical movement. In the premedical selection of participants for physical activity the writer found that, although numerous limiting defects are readily detected, there are others which are not obvious. These are usually detected only when the subject's inability to perform physical activity is noted. The performance of the test exercise has proved very useful in this connection.

As shown in Table 14, all of the good condition group executed the test exercise without difficulty. An inspection of the medical records of these cases showed that no limiting defects were present. Thirteen, or 6 per cent, of the group not in good condition were unable to execute the standard exercise. The conditions responsible for the failures were as follows: 11 were so corpulent that the required bending could not be performed; 1 had a spinal injury as a result of a fall that made the extension of the legs painful; 1 had a stiff knee due to an injury. An inspection of the medical records of the 219 cases not in good condition that were able to execute the test exercise revealed that no defects that limited motor movement were found by the examiner. All of these subjects were individuals who voluntarily applied for admission to a physical education program. This may account for the relatively few disabilities found, for individuals with such defects do not usually seek to enter physical education programs—with the exception of the corpulent, who enter for the purpose of weight reduction.

### REACTIONS WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| *Criteria* | *Motor Movement* |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that reaction is normal. | Motor movement not limited. |

| *Questionable Reactions* | |
| --- | --- |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition. Found in pathological individuals. Investigators agree that the reaction is a pathological symptom. | Limited motor movement. |

SUMMARY AND CONCLUSION

The ability to execute the test exercise was used as a test of physical disability. Two hundred and seventy-one applicants for admission to a physical education program were tested.

All individuals in good or excellent condition executed the test exercise. The medical records of these cases showed no defects which seriously limited physical movements.

Thirteen out of 232 individuals (6 per cent) not in good or excellent condition were unable to execute the test exercise because of corpulency and other defects. The medical records of the 219 cases in this group who executed the test revealed no defects which limited physical movement.

Inability to perform the test exercise has been taken as an indication of limited motor movement.

### *Item 7: Physical Ability*
### (*Time Required to Perform Standard Exercise*)

GENERAL STATEMENT

The ability of the neuromuscular system to function with efficiency and power, i.e., physical ability, is an indication of physical condition, for activity is a correlative of health. Since abundant health is positive and dynamic, and expresses itself in coordinated movements quickly and efficiently performed, freedom from discernible defects is not sufficient as a measure of condition, and physical ability must also be measured.

DATA

The time required to perform the standard exercise of four front leaning rests, executed at maximum speed, was used as a measure

of physical ability. The data are presented in Table 15, below.

Smiley and Chamberlain [130] studied the relationship between physical fitness and health. Sixty-five college students were selected at random. Each student was given a complete medical

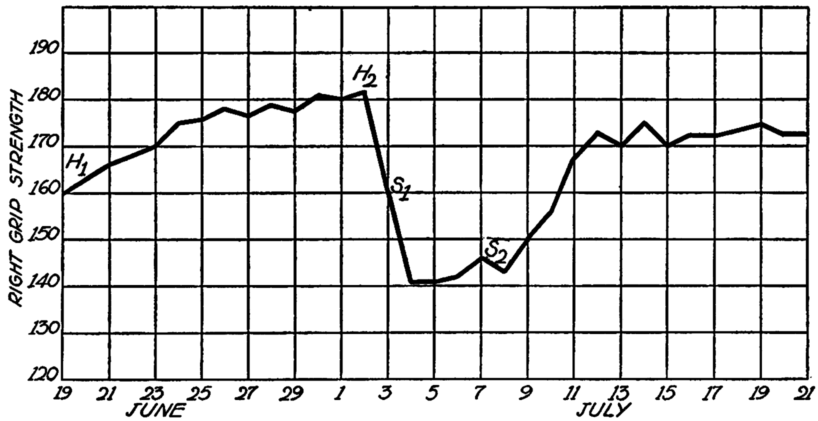
TABLE 15

TIME REQUIRED TO PERFORM FOUR STANDARD EXERCISES

| Performance Time (Seconds) | Number of Cases | | Per Cent of Group | |
|---|---|---|---|---|
| | In Good or Excellent Condition | Not in Good or Excellent Condition | In Good or Excellent Condition | Not in Good or Excellent Condition |
| 17.5 | | 1 | | .5 |
| 16.5 | | | | |
| 15.5 | | 5 | | 2.3 |
| 14.5 | | 7 | | 3.2 |
| 13.5 | 1 | 7 | 2.6 | 3.2 |
| 12.5 | | 15 | | 6.8 |
| 11.5 | 2 | 18 | 5.1 | 8.2 |
| 10.5 | 6 | 43 | 15.4 | 19.5 |
| 9.5 | 9 | 44 | 23.1 | 20.0 |
| 8.5 | 16 | 53 | 41.0 | 24.0 |
| 7.5 | 3 | 23 | 7.7 | 10.5 |
| 6.5 | 2 | 4 | 5.1 | 1.8 |
| Total | 39 | 220 | 100.0 | 100.0 |
| Range | 6.2 to 13 | 6.2 to 17 | | |
| | | | Difference | Standard Error of Difference |
| Mode | 8.5 | 8.5 | | |
| Median | 8.9 | 9.68 | .78 | .32 |
| Mean | 9.14 | 10.02 | .88 | .34 |
| Standard Deviation | 1.35 | 2.03 | .68 | .24 |

examination and rated in one of three categories, as follows: markedly superior, A; average functional health, B; impaired efficiency, C. Following the medical examinations each student was given the Rogers Strength Test, and rated A, B, or C according to the Physical Fitness Index. The two sets of ratings were compared. The results were as follows:

1. The P. F. I. rating agreed with the medical rating in 36 out of 42 average subjects.




$H_1$–$H_2$ Period of health with heavy daily labor
$S_1$ Mild attack of la grippe or influenza begins
$S_2$ Illness ends

FIGURE 2

RELATION BETWEEN STRENGTH OF GRIP AND PHYSICAL CONDITION FOR ONE INDIVIDUAL

(Constructed from Rogers' Data [111])

2. The P. F. I. rating agreed with the medical rating in 3 out of 5 superior cases.

3. The P. F. I. rating agreed with the medical rating in 13 out of 19 handicapped cases.

4. In the entire group the two ratings agreed in 52 out of 65 cases—an average of 80 per cent agreement.

Rogers [111] studied the relation between strength, as measured by the right grip, and physical condition, as measured by the presence or absence of la grippe or influenza. His data are given in Figure 2.

## OPINIONS OF INVESTIGATORS

Further evidence of a non-statistical nature concerning physical ability follows.

*Rogers* [111]

"The relation of the effective condition of voluntary muscle tissue to other organic conditions is just beginning to be recognized; but experiences are multiplying which reveal, beyond peradventure, the truth

of the following rule: *Practically every change in the condition or functioning of the vital organs has a corresponding change in the condition or functioning of voluntary muscles.*

"The reasonableness—even inevitability—of this proposition will be manifest to physiologists. Philosophers, especially in physical education, may go further: if muscles could maintain their powers in the presence of organic deficiencies or diseases, the latter would be inconsequential! For it is the prime function of respiration, circulation, digestion, elimination, and even cerebration, to maintain the effectiveness of muscles as means of locomotion and manipulation. . . ."

*Rogers* [107: 123]

"The best proof of the validity of the strength tests as measures of power to be active is yielded by observations available to all. Activity is restricted by disease, especially when the patient is bed-ridden. Such patients lose their strength rapidly: the muscular weakness of invalids is proverbial. Their fitness for 'purposeful physical activity' is admittedly low. It is instructive, too, to observe the rapid improvement in strength of convalescents. We say they are 'growing stronger.' We observe their muscles gaining in power. We mean that their 'physical fitness for life activities' is improving. Again, the health *and strength* of athletes are highly correlated. One knows from their reputations that they are athletes: one observes their muscles to be well-developed: one knows that athletes must be in good health to be successful. 'The correlation coefficients must be high.' "

DISCUSSION

All measures of the good condition group are less than the corresponding measures of the not in good condition group in Table 15. The differences between the medians and between the means are reliable at the .015 level and .01 level respectively. The difference between the standard deviations is 2.8 times its standard error, and is reliable at the .005 level.

In the good condition group no reactions slower than 13 seconds are found; in other individuals reactions as slow as 17 seconds are found. The reactions that are peculiar to individuals not in good condition are those slower than 13 seconds. However, as Table 15 shows, 38 out of the 39, or 97.4 per cent, of the good condition cases, fall within the range 6–11.9 seconds, and 11 seconds is the last frequency in which more than one good condition case occurs. Therefore, with the exception of one good condition

case with a reaction of 13 seconds, reactions of 12 seconds or more were peculiar to individuals not in good condition.

The study by Smiley and Chamberlain shows a definite relationship between functional health and physical condition, for the correlation between medical ratings and the Physical Fitness Index is $r = .60$. As Rogers [107: 125] has pointed out, this relationship is higher than that found between the first I. Q.'s and teachers' judgment.

It is so generally recognized that numerous diseases and disorders may deplete the reserves of the body and make physical movement difficult, if not impossible, that few writers have discussed this point. The study by Rogers graphically portrays (Figure 2) this relationship between physical strength and physical health in one individual with a particular disorder. Here are shown a rapid decline in strength after the beginning of the inspection, constant low physical performance during the inspection, and a rapid rise in strength upon recovery.

The opinions cited—all that could be found bearing upon this point—clearly state Rogers' opinion of the inherent relationship between the functional condition of the neuromuscular system and the condition of the entire body.

## REACTIONS WHICH SATISFY CRITERIA

When the criteria are applied to the data the following conclusions are indicated.

| Criteria | Physical Ability |
|---|---|
| *Normal Reactions* | |
| Found in individuals in good or excellent condition. Investigators are in agreement that reaction is normal. | Movements are coordinated, powerful, efficient, and quickly performed—test exercise performed in 13 seconds or less. |
| *Questionable Reactions* | |
| Not found in individuals in good or excellent condition. Found in individuals not in good or excellent condition. Found in pathological individuals. Investigators agree that the reaction is a pathological symptom. | Movements are not coordinated, powerful, efficient, and quickly performed—test exercise performed in 13.1 or more seconds. |

### SUMMARY AND CONCLUSION

Physical ability—the functional ability of the neuromuscular system—is an important aspect of physical condition. The time required to perform four standard exercises at maximum speed was used as a measure of this characteristic.

The reactions, speed of performance, of men in good condition were compared with the reactions of other men. The reactions of good condition cases tended, on the average, to be quicker than those of other cases, and no good condition case exceeded thirteen seconds. Reactions as slow as 17 seconds were found in other individuals. Of the good condition cases, 97.4 per cent had reactions quicker than 12 seconds. Reactions of 13 or fewer seconds satisfied the criteria for normal reactions.

Studies and opinions of other investigators were reported. These are in agreement that there is a definite relationship between physical condition and physical performance.

## Critical Scores

In this study the significance attached to, or the interpretation given, an individual's score was determined by the position of that score with reference to the critical score. The method of locating these critical scores is, therefore, of considerable importance, and for this reason, it seems desirable to bring together all discussion pertinent to this subject.

Two closely related, but different, critical scores are used in this study. These are as follows:

1. Critical scores between normal and questionable reactions in the specific populations, or subjects, studied.
2. Critical scores between normal and questionable reactions in the general population.

The critical scores in the specific populations studied were found by comparing the reactions of "normal" men with the reactions of other men. The distinguishing difference between the two groups was in the greater variability of the not in good condition cases, that is, the range of the reactions found for nor-

mal individuals was less than, and a part of, the total range of the reactions of other men. In each total range there were one or more critical scores at which the significance of the scores appeared to change. These critical scores occurred at the extremities of the normal ranges.

It is unfortunate, from the standpoint of the reliability of results, that the distinguishing measures between the two groups are the ranges, and that the critical scores occur at the extremities of the normal range, for the range is a relatively unreliable statistical measure. That is to say, if the study were repeated with a similar, but different, group, different results might be obtained as a single atypical normal case might change the normal range, and thereby change the location of the critical score. This prevents complete reliance being placed upon any single set of data and explains, at least in part, why after two thousand years of study there is not closer agreement concerning what constitutes normal reactions in these items. One of the objectives of this study was the accumulation of data which would contribute toward the solution of this problem. Additional ranges from numerous future studies by other investigators, involving many subjects, must also be determined and all data compared before it can be definitely determined what constitutes a normal reaction. To facilitate this comparison the actual limits of our normal ranges have been stated in the previous treatment of results.

Since the extremities of the normal ranges in the experimental groups were not suitable for locating the critical scores between normal and questionable reactions in the general population, a more reliable method was necessary.

The possibility of using the standard deviation in locating critical scores was first investigated, as the standard deviation is the most reliable measure of variability. In this method the critical scores are located a uniform number of standard deviations from the mean. As the probable per cent of cases included within a given number of standard deviations can be determined for the normal distribution, it is possible to include within the general normal reaction range any desired per cent of the good condition cases if the distributions are normal. However, the distributions

in several of the items were not normal; therefore this method was not suitable.[11]

The second method considered was the use of percentiles. By this method the critical scores are so placed as to include any given per cent of good condition cases. Since normal distributions are not required, this method was suitable for the data. It was decided to use the percentile method for locating critical scores. However, a further point remained to be settled, namely, the per cent of the experimental normal group which should be included within the general normal reaction range.

Any selection of a critical score is necessarily arbitrary. Among the many possible criteria, the following were considered:

1. That score at which 1 per cent of the normal, or good condition, group might be expected to be excluded.
2. That score at which 5 per cent of the normal, or good condition, group might be expected to be excluded.

The results obtained from the use of these methods are shown in Table 16.

TABLE 16

LOCATION OF CRITICAL SCORES WHEN (1) NONE; (2) UPPER 1 PER CENT; AND (3) UPPER 5 PER CENT OF NORMAL GROUP IN EXPERIMENTAL STUDIES ARE EXCLUDED

| Per Cent of Normal Group Excluded | Location of Critical Score | | | | |
|---|---|---|---|---|---|
| | Vertical Pulse Rate | Postural Pulse Rate Change | Increase in Pulse Rate | Time to Return to Normal | Time to Perform Exercise |
| None | 102 | 15 | 58 | 127.5 | 14 |
| 1 | 101.0 | 14.4 | 56.5 | 127.1 | 13.6 |
| 5 | 97.4 | 12.6 | 50.4 | 125.2 | 11.5 |

Criterion 2, the score at which 5 per cent of the good condition group might be expected to be excluded, was selected for the location of the critical scores in the general population. This criterion provided a safety factor against possible shrinkage of the normal

[11] The standard deviations of good condition scores are given in Table 22, page 151.

range which might be shown in future studies without materially reducing the range of the good condition groups.

The 95th percentile of the good condition ranges, as shown in the experimental studies, was found. The critical scores between normal and questionable reactions in the general population were placed at this point. In the vertical pulse rate item there are critical scores at both ends of the good condition range. The lower critical score was placed at the 5th percentile. The critical scores which resulted are as follows:

| *Item* | *Actual Critical Score* |
|---|---|
| Vertical pulse rate | 97.36<br>66.9 |
| Postural pulse rate change | 12.6 |
| Increase in pulse rate | 46.8 |
| Time to return to normal | 118.88 |
| Time to perform exercise | 11.52 |

## Summary

In this chapter, the results of studies undertaken to establish the normal and questionable reactions in the items of the test are given.

Criteria for normal and questionable reactions were established, and the reactions which satisfied these criteria were determined for the populations studied. In these studies, the critical scores occurred at the extremities of the normal, or good condition, range. Because of the unreliability of the extremities of a range, this method was unsuitable for the prediction of the normal range in other populations. The critical scores between normal and questionable reactions in the general population were placed at the 95th percentile of the good condition range to increase the reliability of these scores.

# CHAPTER V

## METHOD OF ADMINISTERING AND SCORING

The proposed test, although composed of simple items, is, paradoxically, not easy to administer, as numerous observations must be made within a few minutes. These observations consist of: (1) the horizontal pulse rate; (2) the vertical pulse rate; (3) the ability or inability to execute the standard exercise; (4) the time required to perform the movements; (5) the pulse rate immediately after exercise; (6) pulse rates each fifteen seconds; and (7) the character of the respiration after executing the standard exercise.

The horizontal and vertical rates present no unusual difficulties, for they are determined in the usual manner. The five remaining observations are taken during, and after, the test exercise, and must be made in their proper sequence. This sequence is as follows:

1. The necessary commands for the execution of the standard exercise are given.
2. The subject performs the exercise once, as instructed.
   a. The ability or inability to execute the required movements is noted—Limited Motor Movement Test.
3. The subject then performs the standard exercise four times at maximum speed.
   a. The time required to perform the four exercises is taken —Time to Perform the Exercise Test.
   b. The character of the respiration immediately after the completion of the exercise is noted, as explained on pages 102-104—Breathlessness After Activity Test.
   c. The pulse rate during the first fifteen seconds after the completion of the exercise is noted. This rate multiplied by four is the exercise rate. Exercise rate minus vertical rate is the Increase After Exercise Test.

*d.* The pulse rates are then counted for each fifteen seconds until the rate returns to the vertical rate. The length of time required is the Time to Return to Normal Test.

Because of the rapidity with which the necessary observations must be made, some dexterity in the handling of equipment is necessary. The following method is recommended:

1. The examiner should be seated at a desk or table with the necessary watch,[1] paper, and pencil before him. A right-handed examiner should sit with his right side toward the desk. There should be sufficient space to the left and in front of the examiner for the subject to execute the test exercise.

2. The examiner uses his left hand to take the pulse rates, and his right hand to manipulate the watch, and to record.

3. The method of recording recommended is a simple, horizontal listing of the rates as they occur.

*Example:* 17–17 / 22–22 / 8 2/5 / 35–33–
28–26–24–22–22 B–sd

The first series of numbers to the left (17–17) are the horizontal rates; the second series (22–22), the vertical rates; the third (8 2/5), the time required to perform the exercise; the fourth (35 . . . 22), the pulse rates after exercise. The notation B–sd signifies Breathing—slightly disturbed. All pulse rates are recorded as taken, for fifteen second intervals. The first rate following the performance time is the Exercise Rate. The time required for the pulse rate to return to normal after exercise is found by counting the number of rates recorded to the right of the performance time up to, and including, the first uniform rate. In the illustration there are six such rates (35–33–28–26–24–22). As each rate represents a period of fifteen seconds the time required was six times fifteen seconds, or ninety seconds.

As is often the case, the detailed written instructions appear much more complicated and involved than the actual procedures. Experience in teaching this test has shown that the method of administration is easily learned. There is only one observation

[1] A stop watch, although not essential, is preferable.



that is difficult—the determination of the character of respiration at the completion of the exercise. This observation is made while the pulse rates are being taken, and until the examiner becomes experienced in the counting of pulse rates difficulty may be experienced. If, because of inexperience or for other reasons, the character of respiration is not observed, the examiner should continue with the test. After all other observations are made, the subject should be instructed to repeat the test exercise, and the character of the respiration should then be noted.

## The Method

The determination of the horizontal pulse rate presents some administrative difficulties as a comfortable couch or support must be provided (the floor is not suitable), and sufficient time allowed for the pulse rate to reach its minimum. In numerous testing situations, these conditions are difficult to provide. For this reason, a "Standard Form" of the test, which includes all items except the postural pulse rate change, has been provided. To this form, the postural pulse rate item may be readily added by examiners who desire to include it.

## The Standard Form

The heart rate is taken—with the subject standing, and at rest—for fifteen seconds with a stop watch. Following this, if desired, the heart may be auscultated for murmurs, etc., in the usual manner. The rate should be taken for successive fifteen-second intervals until two consecutive intervals yield the same rate. This rate is called the "vertical rate.".

If the vertical rate is between 72 and 92 [2] beats per minute, the examination is continued; if the rate is below or above this range, the test is stopped. In the latter case, extra-cardiac factors, such as emotional stimulation, should be suspected and an effort made to eliminate them. With the subject in a resting position, an attempt should be made to establish rapport. The subject should

[2] See page 101 for explanation of these rates.



then be retested in the standing posture, and if the rate is not within the proper range the subject is considered to be in questionable physical condition. If the rate is within the proper range, the examination is continued. The subject executes each movement as given. The procedure is as follows:

*Examiner:* I want you to do a little exercise to get your heart working, so please do *exactly* as I say. Bend your knees, and place your hands flat on the floor in front of you.

(Subject performs movement)

*Examiner:* Jump your legs straight out to the rear, and leave them there.

(Subject performs movement)

*Examiner:* Jump your legs back.

(Subject performs movement)

*Examiner:* Stand up.

(Subject performs movement)

The examiner carefully observes the subject's ability or inability to execute the required movements. If the subject is unable to execute the movements, the examination is stopped and the cause investigated; otherwise, the examination is continued.

*Examiner:* I want you to do four of these as quickly as possible when I say, "Go!" Do you understand? Down–out–back–and–up, four times (the examiner demonstrates a four-count exercise with his hand—one–down, two–out, three–back, four–up) as quickly as you can. Are you ready? Get set, Go!

The examiner starts the stop watch at the word "Go."

After giving the command "Go!" the examiner should note whether the subject is able to perform the four movements correctly at maximum speed. Minor variations in form may be permitted; however, in the second position the subject should be required to extend fully his legs to the rear so that his back is straight, and at completion of each exercise to assume an erect position. Occasionally, active subjects, in an attempt to secure a good performance, will execute the movement as a two-count exercise. Instead of being in the deep-knee bend position at the end of the first movement, they will be in the front leaning rest



position. This is accomplished by throwing the feet to the rear and falling on the hands from the erect position. The norms given are for the four-count exercise, and they will not be valid if the exercise is changed or modified.

If the subject is unable to perform the test successfully after receiving the standard instructions, the testing should be stopped and additional instructions given until successful performance is assured. After a rest period of sufficient duration to allow the heart to return to normal, the testing is resumed as follows: "Are you ready? Get set. Go."

When the fourth exercise is completed, the watch is stopped, and the time is recorded. This is the "physical ability time." Immediately, the heart rate is taken for fifteen seconds, and recorded. This is the "exercise rate." While the exercise rate is being taken, the character of the respiration is noted.

The heart rate is then taken for successive fifteen-second periods until it returns to the vertical rate. The length of time required is called the "time to return to normal."

The results are evaluated as shown in Table 17.

The reliability of scores in the several items has been determined experimentally (see Chapter VII, page 126), and the maximum error to be expected has been ascertained. In pulse rate items, the maximum error to be expected is one beat in fifteen seconds, or four beats per minute. It is therefore possible that a vertical pulse rate of 100 beats a minute, a questionable reaction, may, through error, be recorded as a rate of 96. To insure reliability, all scores within the maximum error to be expected of the critical score are considered questionable, and the subject should be retested until a definitely reliable result, as demonstrated by similar scores, is obtained.

In the Time to Perform the Exercise item, the maximum error to be expected is one second. All scores between 10 2/5 seconds and the critical score (11 2/5 seconds) should be tested for reliability, as previously explained.

In the Time to Return to Normal item, minor variations are also allowed for by considering pulse rates after exercise within four beats of the vertical rate to be the vertical rate.

TABLE 17

SIGNIFICANCE OF SCORES

| Item | Normal Reaction | Normal Reaction Within Maximum Error to Be Expected* | Questionable Reaction* |
|---|---|---|---|
| Vertical pulse rate | 68 to 96 beats per minute | 68 and 96 beats per minute | 100 or more beats per minute<br>64 or less beats per minute |
| Postural pulse rate change.......... | 0 to 12 beats per minute | 0 and 12 beats per minute | 16 or more beats per minute<br>All minus reactions (vertical rate less horizontal rate) |
| Increase in pulse rate............. | 44 or less beats per minute | 44 beats per minute | 48 or more beats per minute |
| Time to return to normal† ........ | 105 seconds or less | | 120 seconds or more |
| Breathlessness after activity.... | Not breathless | | Breathless (elevation of chest wall—forced expiration) |
| Limited motor movement ...... | Motor movement not limited | | Motor movement limited (cannot execute standard exercise) |
| Time to perform exercise......... | 11 2/5 seconds or less | 10 2/5 to 11 2/5 seconds | 11 3/5 seconds or more |

* All questionable reaction scores and all normal reaction scores within the maximum error to be expected of the critical score should be tested for reliability by repeating the test until at least two consecutive tests yield the same result.

† If the constant rate attained after exercise is within four beats per minute of the vertical rate, it should be considered as the vertical rate. For example:

| *Vertical Rate* | *Seconds After Exercise* | | | | | | |
|---|---|---|---|---|---|---|---|
| | *15* | *30* | *45* | *60* | *75* | *90* | *105* |
| 80................. | 120 | 110 | 100 | 84 | 84 | 84 | 84 |
| 80................. | 120 | 110 | 100 | 76 | 76 | 76 | 76 |

The determination of disturbed breathing, or breathlessness, requires further explanation, for although there are two distinct types of breathing, that is, (1) normal breathing or eupnea, and (2) labored breathing or dyspnea, there is no clear natural dividing line between the two. In this study, the types of respiration

which result after completion of the test exercise have been divided into normal breathing and disturbed breathing, or breathlessness. A dividing point between normal and disturbed breathing has also been established. Although based on physiology, the location of this point is necessarily arbitrary. It is therefore essential to the proper use of the test that the characteristics of this dividing point be understood. The following statement by Howell [61: 679-80] is important in that it outlines the physiology of breathing upon which the location of the dividing point in this study is based.

"In general, we distinguish two different forms of breathing movements. The ordinary quiet respirations made without obvious effort, form a condition of respiration designated as eupnea. Difficult or labored breathing is known as dyspnea. . . In ordinary quiet breathing the expiration seems to be *entirely passive,* but some authors state that in all cases it is accompanied by a contraction of the expiratory muscles. The inspiration in man is made by the diaphragm alone or by the diaphragm together with some action of the levatores costarum and the external intercostals. At the end of the inspiration the ribs and diaphragm are brought back to the normal position by purely physical forces,—the elasticity of the distended abdominal wall, the elasticity of the expanded lungs, the weight and torsion of the ribs, etc. As soon as the breathing movements become at all forced the action of the above-named inspiratory muscles is increased in intensity, and the other inspiratory muscles, all elevators of the ribs, come into play. Quiet breathing in man at least is mainly diaphragmatic or abdominal, while dyspnoeic breathing is characterized by a greater action of the elevators of the ribs. *When dyspnea reaches a certain stage the expiration also becomes active or forced. The expiratory act is hastened by a contraction of the abdominal muscles or of the depressors of the ribs,* and indeed the action of these muscles may compress the chest beyond its normal position, so that the expiration is followed by a passive inspiration which brings the chest to its normal position before the next active inspiration begins." [Italics are mine.]

As is indicated by the foregoing statement, several progressive types of respiration following exercise may be distinguished: (1) normal breathing, in which the inspiration is largely diaphragmatic, with little or no elevation of the ribs and passive expiration; (2) slightly disturbed breathing, in which there is a slight elevation of the ribs, with passive expiration; (3) disturbed breathing,

or mild breathlessness, in which there is distinct elevation of the ribs, with forced expiration; and (4) breathlessness, in which there is forced inspiration and expiration, accompanied by symptoms of air hunger. In this study, the dividing line between normal breathing and breathlessness has been placed at type (3), disturbed breathing. Types (1) and (2) are, therefore, both to be considered normal breathing; types (3) and (4), disturbed breathing or breathlessness. The distinguishing, critical characteristics between these two divisions are distinct, forceful elevation of the chest wall, and forced expiration.

In reality the determination of disturbed breathing is a simple matter, and an examiner should experience little difficulty, provided the physiology and characteristics of dyspnea are understood. For examiners who are not familiar with the characteristics of dyspnea the following procedure is recommended:

1. Observe the character and rate of breathing of an individual known to be in good physical condition. (At least the outer clothing above the waist should be removed.)
2. Have the subject perform one test exercise vigorously.
3. Observe the character and rate of breathing after the execution of the test exercise.
4. Have same individual perform a series of test exercises at the rate of approximately one test exercise in eight seconds, with a one-second rest period between each series.
5. Note the character and rate of breathing during the one-second rest period between series.
6. Have subject continue the series until breathing becomes disturbed. Usually good condition cases perform 6 to 8 test exercises before breathing is disturbed.
7. Observe the character of the disturbed breathing.
8. When this disturbed breathing is observed in a subject following the completion of one test exercise, he should be judged to be in questionable condition.

### POSTURAL PULSE RATE CHANGE

The subject should take a recumbent position on a comfortable couch or support. Sufficient time should be allowed for the pulse

rate to assume its resting level. From one to five minutes should be given, depending upon the age, sex, and excitability of the subject. For young subjects unaccustomed to examination procedures a rest period of five minutes is recommended. The pulse rate should be taken for successive fifteen-second intervals until two such intervals disclose similar rates. This is the recumbent rate. The recumbent rate is subtracted from the vertical rate to obtain the postural pulse rate change. The Postural Pulse Rate Change is evaluated in Table 17. The following is an example of the use of the test:

Assume that an individual is examined with the following results:

Vertical rate—19 pulse beats per 15 seconds (76 per minute)
Exercise rate—29 pulse beats per 15 seconds (116 per minute)
Increase after exercise—40 pulse beats
Time to return to normal—105 seconds
Time to perform exercise—10 1/5 seconds
Breathing following the exercise disturbed, short, rapid, and shallow, with noticeable elevation of the chest during inspiration.

Evaluating these results by means of Table 17, it is found that:

Vertical pulse rate is within normal reaction range.
Increase in pulse rate after exercise is within normal reaction range.
Time to perform exercise is within normal reaction range.
Time to return to normal is within normal reaction range.
Physical inability is not present as the subject was able to execute the test exercise.
Breathlessness after activity, the type of respiration exhibited by the subject, constitutes a questionable reaction.

After sufficient rest to eliminate the effect of the previous exercise, the subject is retested for breathlessness after activity. If the respiration is again disturbed, the subject is referred to a physician for diagnosis. If the respiration is not disturbed after the second test, sufficient retests should be given to determine a reliable reaction.

# PART II

## THE VALUES AND LIMITATIONS OF THE TEST

# CHAPTER VI

## VALUES AND LIMITATIONS OF THE TEST IN DETECTION OF DISORDERS

In this and subsequent chapters the studies undertaken to accomplish the fourth objective of this study,[1] the establishment of the values and limitations of the developed test, are described. These studies were necessary, for although it follows directly from the method used in constructing the test that individuals who fail on the test[2] are in questionable physical condition, and that individuals who pass the test have normal reactions in the areas tested, it cannot be assumed that individuals who pass the test do not have limiting defects in other areas. The nature of health is so complex and the causes of disability are so numerous and diverse that it is highly improbable that the seven reactions measured by the test include all limiting defects. It is therefore important to the proper use of the test that its limitations be established.

In the studies which follow an attempt has been made to clarify this point by seeking answers to the following questions:

1. Does the test detect all types of cardiac disorders; if not, which are detected and which are not?
2. What is the diagnostic value of the test in the detection of cardiac abnormalities as compared with other tests?
3. What is the diagnostic value of the test in the detection of other defects?

Studies are also described which aimed to establish the reliability of the pulse rate items, of the time to perform the exercise item, and of the breathlessness test.

[1] The other three objectives are treated in Part I.

[2] Individuals who fail have one or more reactions characteristic of questionable physical condition.

## Diagnostic Value of the Test in Detection of Cardiac Disorders

In determining the diagnostic value of the test, the results of the test were compared with the diagnosis of medical specialists. Three groups of subjects were studied. The first consisted of young males of grammar school age who were regular patients of a cardiac clinic in a New York City hospital; the second consisted of preparatory school boys who had been restricted from exercise by the school physician, and a few controls not so restricted; and the third group consisted of male college students who had been restricted from strenuous exercise by the examining physician, but who were required to participate in regular gymnasium group activities, such as handball, volleyball, and softball. In all cases, the medical diagnosis was unknown when the tests were administered. Collectively, these groups covered the age range in which the test may be used. The results of these studies are given in Table 18.

### DISCUSSION

The subjects in the first study, although all patients in a cardiac clinic, differed widely in their physical condition. The relationship between the severity of the disorders and passing and failing the test is shown in the following comparisons:

| | | |
|---|---|---|
| Practically normal | (Cases 1, 10, 11) | All passed |
| Class 1 | (Cases 4, 5, 7, 9) | Three failed, one passed |
| Class 2A | (Cases 3, 8, 12, 13) | All failed |
| Palpitation | (Case 2) | Failed |
| Class F. | (Case 6) | Failed |

From these data it is evident that the selective value of the test in the detection of cardiac disorders depends upon, and increases with, the severity of the symptoms, for (1) the practically normal cases were not detected; (2) the mild cases (Class 1) were detected in three out of four cases; and (3) the more severe cases were all detected.

In the second study there was also wide difference in the severity of the abnormalities found in the subjects. In four cases (Nos.

TABLE 18

RESULTS OF THE TEST AND DIAGNOSIS OF PHYSICIANS

A. *Patients in a Cardiac Clinic*

| Case | Pulse Rate: Vertical | | Pulse Rate: Exercise Increase | | Pulse Rate: Time to Return to Normal | | Time to Perform Exercise | | Test Reaction |
|---|---|---|---|---|---|---|---|---|---|
| | Reaction | Sigma Score | Reaction | Sigma Score | Reaction (Secs.) | Sigma Score | Reaction (Secs.) | Sigma Score | |
| 1..... | 76 | −0.5 | 32 | −0.5 | 60 | −0.5 | 10 | +.5 | Normal |
| 2..... | 76 | −0.5 | 52 | 1.5 | 75 | | *15** | 4.5 | Questionable |
| 3..... | *128** | 5.5 | 20 | −1.5 | 45 | −1. | *18* | 5+ | Questionable |
| 4..... | 88 | 1.0 | 40 | 0.5 | 75 | | *12* | 2 | Questionable |
| 5..... | *108* | 3.0 | 28 | −0.5 | 60 | −0.5 | 9 | | Questionable |
| 6..... | 92 | 1.5 | 40 | 0.5 | 45 | −1.0 | *15* | 4.5 | Questionable |
| 7..... | 92 | 1.5 | 36 | | 60 | −0.5 | 10 | .5 | Normal |
| 8..... | 96 | 1.5 | 36 | | 45 | −1 | *12* | 2 | Questionable |
| 9..... | *112* | 3.5 | 20 | −1.5 | 75 | | — | — | Questionable |
| 10..... | 88 | 1.0 | 36 | | 60 | −0.5 | 11 | 1.5 | Normal |
| 11..... | 92 | 1.5 | 24 | −1.0 | 60 | −0.5 | 11 | 1.5 | Normal |
| 12..... | *104* | 2.5 | 44 | −1.0 | 75 | | *12* | 2.0 | Questionable |
| 13..... | 96 | 1.5 | 28 | −0.5 | 60 | −0.5 | *12* | 2.0 | Questionable |

*Case* *Diagnosis of Cardiologist*

1. Blood pressure, 122–76; sounds fairly clear; mild mitral, very faint murmur. Recommended that patient pay no attention to his heart, but suggested that he should not overdo.

2. Complains of palpitation; has to sit down until it is over; action regular; possibly mild mitral stenosis murmur; sounds fairly good.

3. Chronic valvular heart disease; double mitral murmur; Class 2A†.

4. In 1927,‡ had chronic valvular heart disease, mitral insufficiency, and stenosis; Class 2B. Has now improved to Class 1.

5. Mitral insufficiency in 1927; now in Class 1.

6. No cardiac lesion; has Chorea; Class F.

7. Mitral insufficiency; condition good; Class 1.

8. In 1927, chronic valvular heart disease; double mitral and aortic insufficiency; Class 2B. Now heart is somewhat overactive; muscular tone good; Class 2A.

9. In 1927, chronic heart disease; double mitral and aortic regurgitation; Class 2B. Now condition very satisfactory; Class 1.

10. In 1927, mitral regurgitation; chronic valvular heart disease; Class 1. Now to be watched for possible sinus infection; negative heart.

11. June, 1928, congenital heart disease; Class 1. Now, heart practically normal.

12. June, 1929, chronic cardiac disease; myocarditis; mitral insufficiency; Class 2A. Now, heart condition satisfactory.

13. In 1927, mitral insufficiency; arythmia; Class 1. October, 1929, extra systole present; muscular tone poor. Now, heart improved; Class 2A.

TABLE 18 (*Continued*)

B. *Preparatory School Pupils*

| Case | Pulse Rate | | | | | | | | Test Reaction |
|---|---|---|---|---|---|---|---|---|---|
| | Vertical | | Exercise Increase | | Time to Return to Normal | | Time to Perform Exercise | | |
| | Reaction | Sigma Score | Reaction | Sigma Score | Reaction (Secs.) | Sigma Score | Reaction (Secs.) | Sigma Score | |
| 1...... | 96 | 1.5 | *48* | 1.5 | 60 | −0.5 | — | — | Questionable |
| 2...... | 80 | | *56* | 2.0 | *180* | 3.5 | — | — | Questionable |
| 3...... | 76 | −0.5 | 32 | −0.5 | 90 | 0.5 | — | — | Normal |
| 4...... | *132* | 5+ | 36 | | 90 | 0.5 | — | — | Questionable |
| 5...... | *156* | 5+ | *4* | −3.0 | 45 | −1.0 | — | — | Questionable |
| 6...... | 92 | 1.5 | 12 | −2.5 | 60 | −0.5 | — | — | Normal |
| 7...... | 88 | 1.0 | 28 | −0.5 | 60 | −0.5 | — | — | Normal |
| 8...... | 88 | 1.0 | 42 | 0.5 | 60 | −0.5 | — | — | Normal |
| 9...... | 96 | 1.5 | 44 | 1.0 | 60 | −0.5 | — | — | Normal |

| *Case* | *Diagnosis of Physician* | *Restrictions* |
|---|---|---|
| 1. | Enlarged heart. | None. |
| 2. | Mitral murmur, also enlargement of heart; no change in last two years; enlargement extending. | No sports. |
| 3. | 1927, heart enlarged; 1928, no change; September, 1928, more enlargement; 1929, more enlargement. | None; allowed soccer; being watched. |
| 4. | Slight aortic systolic murmur. | No competition. |
| 5. | Influenza last spring; recent enlargement of heart. | No competition. |
| 6. | 1926, enlarged heart; 1927, more enlargement; 1928, more enlargement. | None. O.K. to play football. |
| 7. | Slight enlargement of heart. | None. |
| 8. | Heart enlarged one-half inch beyond nipple. | Advised against football; rest suggested. |
| 9. | Enlarged heart. | None. |

* Scores considered *failing* are printed in italics.

† The method of classification used in the Clinic was the Classification of the Association of Cardiac Clinics, which is as follows:

Class 1: Patients with organic heart disease able to carry on ordinary physical activity without discomfort.

Class 2: Patients with organic heart disease unable to carry on ordinary physical activity without discomfort.

Class 2A: Activity slightly limited.

Class 2B: Activity greatly limited.

Class 3: Patients with organic heart disease and with symptoms or signs of heart failure at rest, unable to carry on any physical activity without discomfort.

Class E: Possible heart disease. Patients who show abnormal signs and symptoms referable to the heart but in whom the diagnosis of heart disease is uncertain.

Class F: Potential heart disease. Patients without heart disease, whom it is advisable to follow because of the presence of a history of an etiological factor which might cause heart disease (in such cases the etiological factor should be stated).

‡ Examinations were made in 1930.

TABLE 18 (*Continued*)

C. *College Students*

| Case | Pulse Rate: Vertical Reaction | Vertical Sigma Score | Exercise Increase Reaction | Exercise Increase Sigma Score | Time to Return to Normal Reaction (Secs.) | Time to Return to Normal Sigma Score | Time to Perform Exercise Reaction (Secs.) | Time to Perform Exercise Sigma Score | Test Reaction |
|---|---|---|---|---|---|---|---|---|---|
| 1...... | 80 | 0 | 44 | 1.0 | 60 | −0.5 | — | — | Normal |
| 2...... | 80 | 0 | 44 | 1.0 | 60 | −0.5 | — | — | Normal |
| 3...... | 80 | 0 | 28 | −0.5 | 45 | −1.0 | — | — | Normal |

| *Case* *Diagnosis of Physician* | *Restrictions* |
|---|---|
| 1. Mitral regurgitation well compensated; moderate exercise without distress; recommendation, Group C; temporarily under observation; electrocardiogram taken and examination checked. New recommendation, continue in Group C. | No strenuous activities permitted; regular program of activities including handball, volleyball, softball, and other group games required. |
| 2. Pulmonic murmur on exercise; good quality; slight enlargement of heart in all directions; cardiogram taken. | No strenuous activities permitted; regular program of activities including handball, volleyball, softball, and other group games required. |
| 3. Systolic murmur; loud musical systolic murmur over pericardium; loudest over trisupid; just to left of ensiform; no thrill; cardiogram. | No strenuous activities permitted; regular program of activities including handball, volleyball, softball, and other group games required. |

1, 3, 6, 9), although minor defects were present they did not require, in the opinion of the examining physician, restriction in exercise. In four other cases (Nos. 2, 4, 5, 7) the defects found were of sufficient importance to warrant restrictions. In one case (No. 8) the physician was not certain of the significance of his diagnosis, and the subject was not restricted but was advised not to play football, and to rest. Here again a definite relationship between the selective value of the test in the detection of cardiac disorders is indicated for (1) three of four cases with minor disorders which did not warrant restriction passed the test—the fourth case (No. 1), diagnosed as enlarged heart, failed the test;

and (2) all cases with disorders which warranted restriction failed the test.

All of the subjects in the third study had abnormalities of the heart which, in the opinion of the examining physician, were of such character that (1) strenuous competition was inadvisable, and (2) regular supervised activities, such as handball and volleyball, were desirable. These subjects were not detected by the test.

These three studies of cardiac subjects demonstrate two conditions that arise in the detection of individuals with cardiac disorders: (1) the difficulty of the problem is greatly increased as the individual approaches the normal; and (2) there are two types of defects, structural and functional, which must be detected.

The validity of a functional cardiac test varies with the severity of the disorders in the subjects being tested, for a test may be a valid measure of cardiac disability in disorders of a given severity, and invalid in disorders of lesser severity. Many simple tests will differentiate between cardiacs who are bedridden and varsity athletes, for such patients show numerous symptoms of cardiac insufficiency upon any slight exertion. It is a different, and much more difficult, problem to differentiate among apparently healthy individuals those who should be encouraged to engage in unrestricted competition in all sports and those who should be permitted only supervised activities. Others have noted this, for Wells [144: 44] states that "Functional tests become more difficult the nearer the subject approaches perfect health. A crude test is sufficient to prove that a man is dead; the evidences of failing function abound in the advanced stages of disease; but to determine the condition of an athlete is not easy. For the human organism is so complicated, a dynamic equilibrium of so many varying factors, that the significance of small departures from the expected responses must always be questionable."

The severity of the disorders present in the group being tested is a factor in the validity of functional cardiac tests, and validity must be defined in terms of symptoms.

The second difficulty in detecting abnormal cardiac condition lies in the fact that some of the restricting conditions are organic

while others are functional; that some can be traced to a defect in structure or form, such as a heart valve that does not close properly, while for others no causative structural defect can be found. When tests of function are used to detect cardiac disorders it is necessary that not only their validity in the detection of functional disorders, but also their validity in the detection of structural defects be known.

These two factors which condition the validity of functional cardiac tests—the relationship between the validity of the test and the severity of the disorder, and the presence of two types of defects—have not always been clearly recognized, and the failure to relate studies of validity to these factors is, in part, the cause of the conflicting and confusing findings which have been reported for functional tests. In the conclusion which follows, the validity of the test is defined in terms of both severity of disorders and types of defects.

### CONCLUSION

The Classifications of the Association of Cardiac Clincs afford a convenient means of stating the validity of the test as this plan of classification is based upon both severity of disorders and types of defects. (See Table 18.)

Class 1 is characterized by the absence of symptoms of cardiac insufficiency, although organic disease is present, i.e., the disease condition is so slight or so well compensated for that normal function under ordinary conditions of activity is not disturbed. Although three Class 1 cases were detected in the hospital group, the results of the three studies indicate that the test does not consistently identify individuals with functional cardiac disease without symptoms of cardiac insufficiency (Class 1). This is what is to be expected as the test is composed of functional items, and this category is based upon the absence of functional symptoms.

In our studies of cardiacs, all patients with organic heart disease accompanied with symptoms of insufficiency (Classes 2 and 3), or of such severity as to require restriction from exercise, were failed by the test. These results indicate that the test is satisfactory for the detection of these cases.

Class E—patients with possible heart disease—is a broad classification, for the subjects are so classified for numerous reasons. However, since abnormal symptoms and signs are present, those cases which have functional symptoms should be detected by the test.

Class F—patients with potential heart disease—is also a very general classification. Usually, the diagnosis is made upon a history of infection, and until destruction of cardiac tissue has occurred symptoms of cardiac insufficiency are usually not found. These cases may therefore not be detected by the test.

Specifically, the answers to the first question, "Does the test detect all types of cardiac disorders; if not, which types are detected, and which are not?" were as follows:

1. The test does not detect all types of cardiac disorders.
2. Patients with cardiac disorders, who at the time of observation have symptoms of cardiac insufficiency following exertion, are detected.
3. Patients with potential heart disease, possible heart disease, and organic heart disease who have never had symptoms of cardiac insufficiency under ordinary conditions of activity or who do not have them at present may not be detected.

## Comparative Value of the Test in Detection of Cardiac Disorders

Two studies were made of the comparative value of the test. These consisted of a comparison with (1) the Michigan State Test, and (2) the Pulse-Ratio Test.

### THE MICHIGAN STATE TEST

The results of the comparison with the Michigan State Test are given in Table 19.

The time required for the pulse rate to return to normal, one of the measures used in our test, is the basis of the Michigan State Test. The results of the time required for the pulse rate to return to normal after our standard exercise and the results of the

TABLE 19

RESULTS OF THE PRIMARY STUDY TEST AND THE MICHIGAN STATE TEST

| Subject | Time to Return to Normal of Pulse Rate* | | Difference |
|---|---|---|---|
| | The Primary Study Test† | Michigan State Test‡ | |
| M. F. | 60 | 60 | 0 |
| C. D. | 60 | 60 | 0 |
| J. E. | 60 | 75 | +15 |
| R. R. | 75 | 60 | −15 |
| C. N. | 60 | 60 | 0 |
| V. V. | 60 | 75 | +15 |
| P. N. | 75 | 75 | 0 |
| P. G. | 75 | 75 | 0 |
| W. T. | 45 | 45 | 0 |
| A. M. | 60 | 60 | 0 |
| V. S. | 60 | 60 | 0 |
| P. P. | 75 | 60 | −15 |
| P. C. | 60 | 60 | 0 |
| A. H. | 45 | 45 | 0 |
| Mean | 62.14 | 62.14 | 0 |

* Measurement is taken at fifteen-second intervals.
† Exercise—four-count front leaning rests.
‡ Exercise—fifteen-second run in place.

Michigan State Test, as shown in Table 19, are practically identical, the difference in no case exceeding fifteen seconds. Because of the similarity in results, the proposed test may be used to secure the reactions measured by the Michigan State Test. However, when the proposed test is used, six additional reactions are also obtained without any increase in administration time.

## PULSE-RATIO TEST

Sievers [128] used the Pulse-Ratio Test[3] on individuals with (1) functional murmurs; (2) organic lesions; (3) compensated

[3] The Pulse-Ratio Test, the method used by Tuttle and Wells and by Sievers, is based upon a "pulse-ratio" (i.e., the pulse rate for two minutes after exercise divided by the pulse rate for one minute at rest), and consists in finding the pulse ratio after two exercises of different intensities, mathematically determining what the pulse-ratios for an intermediate exercise should be; experimentally determining what the pulse-ratio is after the intermediate exercise; and comparing the mathematically determined pulse-ratio with the experimentally determined ratio.

organic lesions; (4) neurogenic lesions; and (5) questionable condition, and found that subjects with functional murmurs, compensated organic lesions, and neurogenic lesions were not detected by means of this test. Conclusions could not be drawn regarding the questionable cases. The Pulse-Ratio Test did detect non-compensated organic heart lesions. Similar results have also been obtained by Lee [64] and Carpenter [28].

These results are similar to those found for the proposed test, as both measures detect organic heart disease when accompanied by symptoms of cardiac insufficiency (non-compensated organic heart lesions). The two measures, therefore, appear to have similar values in the detection of cardiac disorders.

The Pulse-Ratio Test employs a single measure—pulse rate reaction after exercise—for the detection of one type of disorder—non-compensated organic heart lesions. The proposed test employs this measure and six other measures to accomplish a wider objective—the identification of individuals in questionable physical condition. The information obtained from the use of these additional measures in the proposed test is not available in the Pulse-Ratio Test. The administration time required for the Pulse-Ratio Test is from three to four times that required for the administration of the proposed test.

## Diagnostic Value of the Test in Detection of Non-Cardiac Disorders

To answer the third question, "What is the diagnostic value of the test in the detection of other (non-cardiac) defects?" a comparison was made of the abnormalities found in individuals who pass the test and in those who fail the test. The abnormalities were found by means of medical examinations administered by a registered physician. The standards used in determining what constituted an abnormality were as follows:

*Blood Pressure:* High systolic—greater than 100 plus the age; however, no case was considered high which did not exceed 130 mm; low systolic—less than 100; relaxed—vertical systolic less than horizontal systolic.

*Hemoglobin:* Talquist scale used as recommended by manufacturer; ratings of 75 per cent or less were considered defects.

*Posture:* Harvard scale used; ratings C and D were considered defects.

*Musculature:* Condition of musculature determined by observation, and by palpation of flexed muscles; three classifications reported—good, fair, and poor. Poor musculature was considered a defect.

*Nutrition:* Subjects classified into three groups—good, fair, poor, on basis of observation and comparison with age, height, weight standard. Poor nutrition was considered a defect.

In other items, the customary medical standards of what constitutes an abnormality were used. The results of the comparison are given in Table 20, and in Figures 3 and 4.

Although there are medical standards of what constitutes abnormalities, or deviations from the normal, individual examiners vary in their opinions regarding what constitutes abnormality in individual cases inasmuch as many of these standards are neither exact nor objective. Primarily, the validity of a diagnosis of abnormality, or deviation from the normal, expresses the opinion of the examiner and rests upon his training and ability. This prevents any great reliance being placed upon the results of studies of the frequencies of abnormalities in different groups as found by different examiners. However, the comparison of abnormalities in different groups has been found useful in indicating general trends and tendencies.[4]

In this study, examinations were performed by two registered physicians of considerable experience. One physician performed 198 of the examinations, and the other 60. Because of the relatively large per cent of examinations performed by one examiner, one element of unreliability—variations among individual examiners—tends to be minimized. However, lack of reliable objective tests of abnormalities, or deviations from the normal, prevents the results of this study from being useful for other than the indication of general trends and tendencies.

[4] Medical examinations were used in *Genetic Studies of Genius* [135: 215-51] to secure a basis for generalizing with respect to the health condition of gifted children in general.



## DISCUSSION

Abnormalities are more frequently found in individuals who fail on the test than in individuals who pass. This is shown in all comparisons. The average number found in failed cases is almost twice (75 per cent increase) that found in passed cases (Table 20). In passed cases, the number of defects most frequently found is two; in failed cases, four (Table 20). The difference between the average number of abnormalities found in passed cases and the average number of abnormalities found in failed cases is statistically significant, the difference between the average being more than three times its standard error. There is, however, considerable overlapping of the two groups.

In the thirty items observed by the medical examiners and reported in Table 20-B there are wide variations in both the num-

TABLE 20

ABNORMALITIES

A. *Number of Defects Found in* (1) *Individuals Who Passed the Test; and* (2) *Individuals Who Failed the Test*

| Number of Defects | Passed Group | | Failed Group | |
|---|---|---|---|---|
| | Number | Per Cent | Number | Per Cent |
| 13 | | | 1 | 0.9 |
| 12 | | | | |
| 11 | | | 3 | 2.8 |
| 10 | 3 | 2 | 7 | 6.5 |
| 9 | 1 | 0.7 | 13 | 12.1 |
| 8 | 5 | 3.3 | 15 | 13.9 |
| 7 | 10 | 6.7 | 11 | 10.1 |
| 6 | 13 | 8.7 | 12 | 11.1 |
| 5 | 17 | 11.3 | 14 | 13.0 |
| 4 | 21 | 14.0 | 19 | 17.6 |
| 3 | 18 | 12.0 | 11 | 10.1 |
| 2 | 29 | 19.3 | 2 | 1.9 |
| 1 | 24 | 16.0 | | |
| 0 | 9 | 6.0 | | |
| Total | 150 | 100.0 | 108 | 100.0 |
| Mean | 3.5 | | 6.3 | |
| Standard Deviation | 2.35 | | 2.44 | |
| Standard Deviation of Mean | .19 | | .24 | |

Difference in Average Abnormalities of Passed Group—Failed Group 2.8, $\sigma$.3

## TABLE 20 (*Continued*)

B. ***Abnormalities Found in*** **(1)** ***Individuals Who Passed the Test; and*** **(2)** ***Individuals Who Failed the Test***

| Abnormality Related to | Number of Cases | | | Per Cent of Cases | | |
|---|---|---|---|---|---|---|
| | Passed | Failed | Difference | Passed | Failed | Difference |
| **Blood Pressure** | | | | | | |
| High | 9 | 14 | −5 | 6 | 13 | −7 |
| Low | | 1 | −1 | | 1 | −1 |
| Relaxed | 20 | 20 | | 13 | 19 | −6 |
| | 29 | 35 | −6 | 19 | 33 | −14 |
| Hemoglobin | 63 | 55 | +8 | 42 | 51 | −9 |
| Posture | 30 | 50 | −20 | 20 | 46 | −26 |
| Musculature | 24 | 39 | −15 | 16 | 36 | −20 |
| Nutrition | 32 | 48 | −16 | 21 | 44 | −23 |
| Skin | 16 | 10 | +6 | 11 | 9 | +2 |
| Glands | 50 | 34 | +16 | 33 | 31 | +2 |
| **Hands** | | | | | | |
| Tremor | 4 | 8 | −4 | 3 | 7 | −4 |
| Other | 1 | 1 | | .7 | 1 | −.3 |
| | 5 | 9 | −4 | 3.7 | 8 | −4.3 |
| Arms | 2 | 2 | | 1 | 2 | −1 |
| Genitalia | 5 | 9 | −4 | 3 | 8 | −5 |
| **Hernia** | | | | | | |
| Large ingr. rings | 5 | 5 | | 3 | 5 | −2 |
| Impulse | 4 | 1 | +3 | 3 | 1 | +2 |
| Partial | 3 | 1 | +2 | 2 | 1 | +1 |
| | 12 | 7 | +5 | 8 | 7 | +1 |
| Feet | 38 | 39 | −1 | 25 | 36 | −11 |
| Legs | 2 | 4 | −2 | 1 | 4 | −3 |
| Romberg sign | | 1 | −1 | | 1 | −1 |
| Visceral ptosis | 6 | 10 | −4 | 4 | 9 | −5 |
| Hair | 15 | 11 | +4 | 10 | 10 | |
| Eye reflexes | 1 | 2 | −1 | .7 | 2 | −1.3 |
| Nose | 19 | 15 | +4 | 14 | 14 | |
| Teeth | 33 | 26 | +7 | 22 | 24 | −2 |
| Gums | 9 | 7 | +2 | 6 | 6 | |
| Tongue | 4 | 3 | +1 | 3 | 3 | |
| Tonsils | 38 | 24 | +14 | 25 | 22 | +3 |
| Pharynx | 37 | 16 | +21 | 25 | 15 | +10 |
| Ears | 3 | 2 | +1 | 2 | 2 | |
| Neck | | 1 | −1 | | 1 | −1 |
| **Chest** | | | | | | |
| Questionable | 2 | | +2 | 1 | | +1 |
| Funnel | 2 | 1 | +1 | 1 | 1 | |
| Rickety | 1 | 1 | | .7 | 1 | −.3 |
| | 5 | 2 | +3 | 2.7 | 2 | +.7 |
| Heart | 2 | 12 | −10 | 1 | 11 | −10 |
| Lungs | | | | | | |
| Abdomen | 13 | 16 | −3 | 9 | 15 | −6 |
| Reflexes | 44 | 38 | +6 | 29 | 35 | −6 |

ber of cases and the per cent of the group found with these conditions. The abnormalities most frequently found in the 108 individuals who failed the test are:

| *Abnormality* | *No. of cases* |
|---|---|
| Low hemoglobin | 55 |
| Poor posture | 50 |
| Poor nutrition | 48 |
| Poor musculature | 39 |
| Flat feet | 39 |

These five abnormalities are symptomatic of a run-down, fatigued condition, and when several occur in the same individual at the same time their significance is obvious. The five symptoms in various combinations occurred in the failed group as follows:

| *Number of Fatigue Symptoms* | *Failed Cases* | |
|---|---|---|
| | *Number* | *Per Cent* |
| None | 15 | 14 |
| One or more | 93 | 86 |
| Two or more | 71 | 66 |
| Three or more | 46 | 41 |
| Four or more | 18 | 17 |
| Five | 1 | .9 |

These data reveal a condition that is obvious from a detailed study of the individuals' medical reports, namely, that individuals who fail the test are frequently fatigued, run-down, and in generally poor condition.

In Figure 4 the differences in the per cent of the two groups with each abnormality, as shown in the last column of Table 20-B, are arranged in order of magnitude. The outstanding characteristic of these differences is their wide variation in magnitude.

Five of the seven abnormalities with largest differences in per cent, namely, poor posture, poor nutrition, poor musculature, flat feet, and low hemoglobin, are the items which occur most frequently in failed cases. These items, therefore, not only occur most frequently, but also constitute the major differences between the two groups. The two remaining abnormalities are blood pressure and heart. Blood-pressure abnormalities were also found

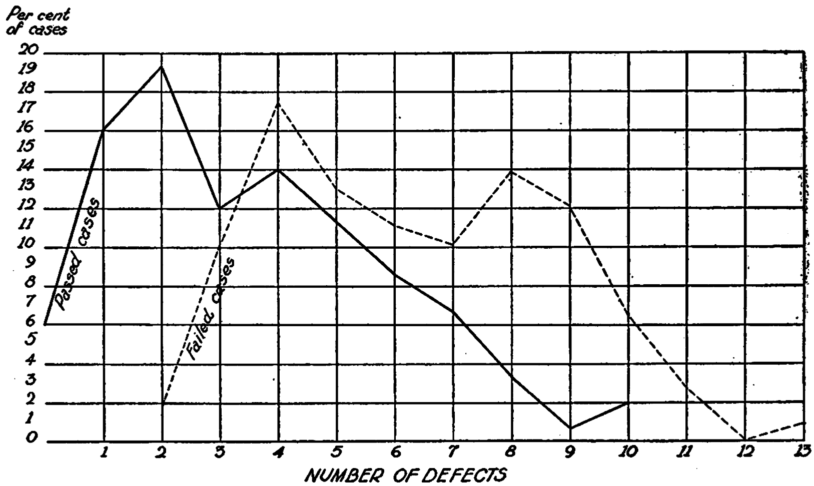



FIGURE 3

PER CENT OF INDIVIDUALS WITH DEFECTS WHO PASS AND WHO FAIL THE TEST

in failed cases—35 cases—seventh in order of frequency (Table 20-B). Heart abnormalities were reported twelve times in the failed group, and two times in the passed group. The relatively few cases reported is what is to be expected, as these conditions occur infrequently in unselected groups.

## SUMMARY

Of the 258 individuals tested, those who failed the test had, on the average, almost twice the number of abnormalities found in individuals who passed.

Few failed cases (14 per cent) were found without one or more symptoms of fatigue and run-down condition, that is, low hemoglobin, poor posture, poor nutrition, poor musculature, and flat feet.

When the difference between the passed and failed groups is measured by the difference in the relative frequency of abnormalities in these groups, low hemoglobin, poor posture, poor nutrition, poor musculature, flat feet, and blood pressure abnormalities were found to be the distinguishing characteristics of failed cases. Most abnormalities were found in both groups.

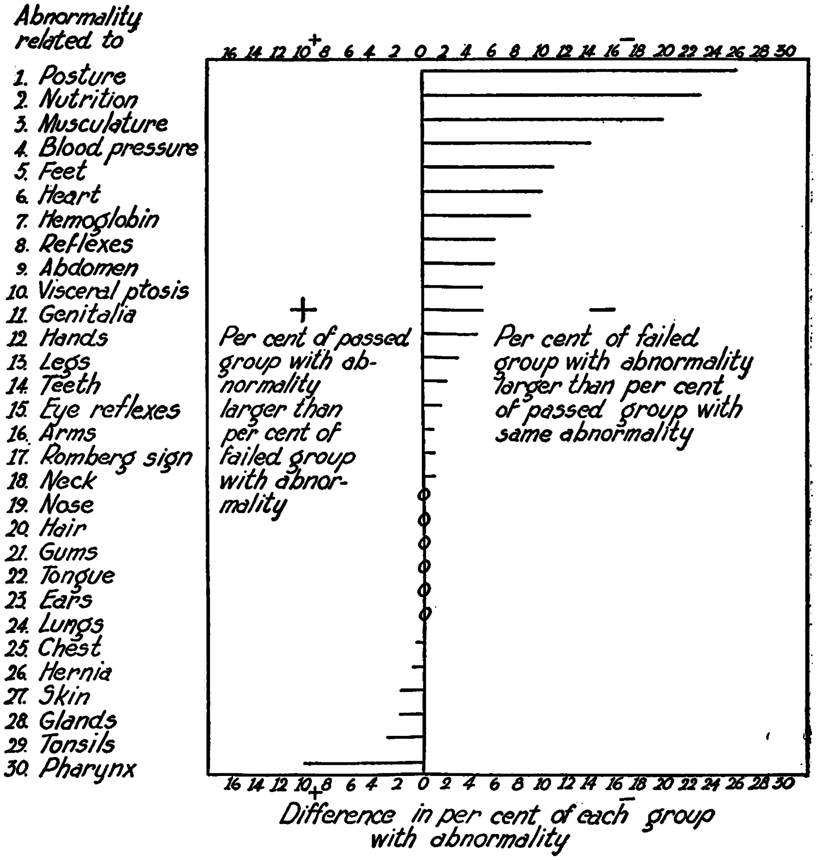



FIGURE 4

DIFFERENCE IN PER CENT OF PASSED GROUP WITH ABNORMALITY AND PER CENT OF FAILED GROUP WITH SAME ABNORMALITY

## CONCLUSION

The diagnostic value of the test in the detection of non-cardiac defects is as follows:

1. Diagnostic value varies with the specific abnormality.
2. Certain defects, specifically those associated with posture, nutrition, musculature, blood pressure, feet, and hemoglobin, are closely associated with failure to pass the test. Other abnormalities were slightly related, or not related at all.

3. As a group, individuals who fail exhibit symptoms of fatigue and run-down condition.

4. It cannot be concluded that non-cardiac abnormalities are not present in individuals who pass the test.

## Summary and Conclusions

The following statements summarize the results of the investigations described in the preceding pages:

1. Cardiac disorders which cause a disturbance in pulse rates, respiration rates, or physical ability were detected by the test.
2. Organic heart diseases which do not cause symptoms of cardiac insufficiency after physical exertion may not be detected.
3. Both the individuals who passed the test and the individuals who failed the test had conditions regarded as abnormalities by physicians.
4. When individuals who pass the test are compared with individuals who fail the test, approximately twice as many abnormalities are found in the "failed" group. The difference between the two groups is largely accounted for by the greater frequency of abnormalities associated with hemoglobin, posture, nutrition, musculature, feet, blood pressure, and the heart, in the failed group.

# CHAPTER VII

## RELIABILITY OF THE TEST ITEMS

THE reliability of a test is determined by the consistency with which it measures a given quality or substance. When consistent or similar results are obtained, the test is reliable; when the results vary, it is unreliable. The reliability of a test is usually determined by correlating the scores made by a given group with a second set of scores made by the same group. This correlation is called the reliability coefficient.

The reliability of functional measures of physical condition has been discussed by Schwartz [124], McCurdy and Larson [77], and Lyth [66]. Schwartz and his associates measured reliability by tests given six months apart, and concluded that "Measures of physical fitness (apart from weight itself, .98) are on quite a doubtful basis. Pulse rate led with a .71, which seems very low when compared with the results obtained by precise measurements on the body. . . ." [124] McCurdy and Larson take issue with this method of determining reliability stating that "The low coefficients of reliability in this study[1] are due to experimental conditions which were improper for a study of reliability, and not to the inaccuracy of the measurement as one would think." [77: 3] Controlling experimental conditions, especially by immediate retesting, they were able to secure reliability coefficients exceeding .90.

In this study, the reliability of the pulse rate items has been determined by both direct or immediate retesting, and by testing over an extended period of time.

### RELIABILITY AS SHOWN BY DIRECT RETESTING

Twenty-seven men were given the test, and retested immediately after. The reliability coefficients were:

[1] The study by Schwartz.

| | |
|---|---|
| Vertical rate | .94 |
| Increase after exercise | .81 |
| Return to normal | .75 |

Several unusual features of the administration and scoring of the test evolved in this study make the results more dependable than is usually the case for measures with the reliability coefficients of the size indicated. This is accomplished by: (1) requiring that no attempt be made to classify an individual until repeated examinations disclose a reliable rate; (2) requiring reexamination of all individuals who fail, and attaching significance only to rates which, upon repeated examination, are found to be reliable; and (3) having a range for passing and failing within which variation does not affect the result.

The effectiveness of these measures is shown by the consistency of test scores. In every case, the interpretation for the first test was the same as that for the retest.

### RELIABILITY AS SHOWN BY TESTING OVER AN EXTENDED PERIOD OF TIME

The pulse rates of seventeen men known to be organically sound were studied over a period of ten days. These subjects were divided into two groups. The first, the control group, consisted of seven men known to be regular in their daily habits. They were required to follow a regular, hygienic routine, and every effort was made to keep their physical condition as constant as possible during the experiment. No variations in general health were reported by this group. The second, or experimental group, was composed of ten men who were irregular in their daily habits. No attempt was made to control their daily hygiene, and numerous instances of late hours, excessive eating, drinking, and smoking were reported. The examinations were given in the late afternoon and evening, both before and after the evening meal. From three to seven observations were made on each individual. The first observation was considered the basic rate, and variations of subsequent examinations were calculated from that point. For example, a variation of twenty-four beats indicates that at least one subsequent rate varied from the original rate by this amount.

Similarly, a zero variation indicates that at least one subsequent rate coincided with the original rate. The results of the observations are given in Table 21.

TABLE 21

VARIATIONS IN PULSE RATES DURING TEN DAYS OF MEN WITH (1) REGULAR HABITS; AND (2) IRREGULAR HABITS

| Item | Men With Regular Habits | | | Men With Irregular Habits | | |
|---|---|---|---|---|---|---|
| | *N* | Range of Variations | Mean Variation | *N* | Range of Variations | Mean Variation |
| Vertical pulse rate (per minute) | 7 | 0–24 | 7.1 | 10 | 0–40 | 18.0 |
| Increase in pulse rate after exercise (per minute) | 7 | 0–14 | 8.3 | 10 | 0–48 | 21.4 |
| Time for pulse rate to return to normal (seconds) | 7 | 0–14 | 7.0 | 10 | 15–90 | 33.0 |

Individual variations in the pulse rate at rest and after exercise, and in the time required for the pulse rate to return to normal after exercise, occurred in both the control and the experimental group. The variations of rate in men who followed a regular, hygienic routine were small, and in no case was the test score changed from normal to questionable. The men who were irregular, kept late hours, etc., showed considerable variation, and in seven of the ten cases these variations were sufficiently large to change the score from normal to questionable.

In uncontrolled situations, such as usually occur in routine examinations, organically sound individuals who would ordinarily pass the test may fail because of temporary functional disability produced by late hours, fatigue, etc.

### SUMMARY AND CONCLUSION

The reliability of the pulse rate items was determined by direct or immediate retesting, and over an extended period of time. Reliability coefficients of from .75 to .94 were found. In the proposed test, individuals with irregular pulse rates are not considered, and only reliable pulse rates are used as an indication of questionable

physical condition. This is accomplished, as previously explained, by requiring (1) at the start of the test, that the pulse rate be taken repeatedly until a reliable rate is obtained; (2) retests when a questionable reaction is obtained; and (3) retests when the score obtained is within the maximum error to be expected of the critical scores, that is, retests differing from the first to an amount greater than the maximum difference to be expected from two independent observers. As a result, the individual diagnosis or score of the test is more reliable than the reliability coefficients would indicate. In the group studied, there were no changes in diagnosis upon immediate retesting.

The consistency of the pulse rate was studied by observing the rates of seventeen men for ten days. When the physical condition remained unchanged, the variation in pulse rate was small, and no change in diagnosis occurred. When the physical condition fluctuated, the variation in pulse rate was large, and in many instances the diagnosis was changed.

The pulse rate items used in this study are sufficiently reliable to be measures of physical condition. The methods of increasing the reliability of the results are effective, and interpretations or diagnosis are highly reliable, when physical condition remains unchanged. When the physical condition of the subject varies, the diagnosis varies. Late hours, overwork, overindulgence, etc., may so influence the physical condition of organically sound individuals that they will fail the test.

## Further Studies of Reliability

The previously mentioned studies of reliability dealt only with that aspect of reliability which relates to variations in the condition of the subject. The studies here described relate to the reliability of examiners in making the observations necessary in administering the test.

In the administration of the test, four types of observations are necessary, namely: (1) counting the pulse rate; (2) timing the period required to perform the test exercise; (3) estimating the degree of breathlessness following the execution of the test exer-

cise; and (4) noting the inability of the subject to make the movements required by the execution of the test.

Studies of the reliability of scores obtained by different examiners were made of the first three types of observations; the fourth type of observation, noting when the subject is unable to perform the test exercise, was not studied since it is a simple statement of fact concerning the subject's ability to execute the four carefully defined movements of the test exercise.

### RELIABILITY OF PULSE RATES COUNTED BY DIFFERENT EXAMINERS

Two men without special training or experience in the counting of pulse rates were used as examiners. Both examiners (A and B) determined the frequency of the pulse of the subject by palpating the radial artery of the right arm. The fingers of the two examiners, although close, did not touch or overlap. Time was measured for fifteen seconds by one of the examiners, using a fifth-second stop watch placed between them. The results were as follows:

| | | |
|---|---|---|
| Total number of tests made | 50 | |
| Number and per cent of tests in which both examiners obtained identical results | 44 | 88% |
| Number and per cent of tests in which examiners varied one beat | 6 | 12% |
| Correlation between results of Examiner A and Examiner B | $r = .97$ | |

(In no test did the examiners vary more than one beat.)

### RELIABILITY OF TIME REQUIRED TO PERFORM THE TEST EXERCISE AS MEASURED BY DIFFERENT EXAMINERS

Two examiners recorded independently the time required by the subject to perform the standard exercise. Each examiner operated a fifth-second stop watch. The watches were started at the word "Go," and were stopped when each examiner judged the exercise completed. The results were as follows:

| | |
|---|---|
| Number of tests made | 50 |
| Range of differences between examiners | — 1 sec. to + .6 sec.[2] |

| | |
|---|---|
| Mean variation of the differences | —.06 sec. |
| Standard deviation of variations | .3 sec. |
| Correlation between the scores of Examiner A and Examiner B | $r = .93$ |

RELIABILITY OF MEASURES OF BREATHLESSNESS AS MADE BY DIFFERENT EXAMINERS

The character of the respiration after executing the test exercise was judged by three judges (1, 2, and 3). Prior to testing, each examiner read the instructions for administering the test. Each examiner scored independently. The results were as follows:

| | | |
|---|---|---|
| Total number of tests given | 103 | |
| Number and per cent of tests in which all three judges agreed in ratings | 91 | 88% |
| Number and per cent of tests in which Judge 1 and Judge 2 agreed | 97 | 94% |
| Number and per cent of tests in which Judge 1 and Judge 3 agreed | 94 | 91% |
| Number and per cent of tests in which Judge 2 and Judge 3 agreed | 94 | 91% |

The three foregoing studies indicate that the tests are reasonably reliable[3] when administered by different examiners, for the variations in scores are small, the per cent of agreement is large, and the coefficient of reliability is high.[4] The final results of the tests, however, are more reliable than the reliability coefficients indicate, for in all cases where the score is within one maximum error to be expected of the critical point of the test, the subject is retested until a thoroughly reliable score is obtained. For example, in the "Time to Perform the Exercise" test the critical

[2] The time recorded on watch B was subtracted from the time recorded on watch A. When the time recorded on watch A was greater, the difference was considered positive. When the time recorded on watch B was greater, the difference was considered negative.

[3] A reliability coefficient of .90 or better between duplicate forms of a test for unselected groups of the same age is considered sufficient by makers of general intelligence tests. [51: 269]

| [4] Reliability Test | Maximum Variation | Per Cent of Agreement | Reliability Coefficient |
|---|---|---|---|
| Pulse rates | 1 beat | 88 | .97 |
| Time for exercise | 1 second | | .93 |
| Breathlessness | Disturbed-normal | 88-94 | |

score is 11 2/5 seconds. The maximum error found between examiners was one second. In all cases where scores are obtained between 10 2/5 and 12 2/5 seconds (critical score $\pm$ maximum error), the subject must be retested until the reliability of the score is established, that is, until at least two consecutive trials give the same results.

This unusual method of scoring and administering increases the reliability of the final results for in each test there is a critical score, or point, which determines the final significance of scores. Results on one side of this point indicate passing and results on the other side indicate failing. Errors due to unreliability do not affect the final result unless these errors change the position of the score in reference to the critical point of the test. Since the reliability of all scores which fall within the range of probable maximum error must be definitely established by retesting, the influence of errors of unreliability between examiners should be eliminated.

## Summary and Conclusions

In this chapter have been described the studies undertaken to establish the reliability of the test items. Two aspects of reliability were investigated: (1) variations in the condition of the subject, and (2) the reliability scores of different examiners.

Reliability coefficients from .75 to .97 were obtained. The results of the test are more reliable than these coefficients indicate, for the following reasons:

1. Only individuals with reliable vertical rates are classified.
2. All individuals with questionable reactions are re-examined.
3. All scores within the maximum error to be expected of the critical scores are retested for reliability, and only reliable rates are considered significant.
4. Variations within the range for normal and for questionable reactions do not affect the result.

These studies showed that the items used in the tests are sufficiently reliable to be used for the intended purpose.



## CHAPTER VIII

### GENERAL SUMMARY AND CONCLUSION

THE objectives of this study were: (1) to ascertain the methods of measuring physical capacity which can be administered with minimum equipment and time by examiners not trained in medicine; (2) to discover the significance and values of these measures; (3) to build these measures into a simple, quickly administered test; and (4) to establish the values and limitations of the resulting test.

Numerous studies and investigations were undertaken to accomplish these objectives, and the detailed findings have been recounted in the previous chapters. It remains only to consider the significance of these studies as a whole, and to discuss a few of the results. In the discussion which follows, the studies will be considered as they relate to the four objectives.

### SUITABLE METHODS OF MEASURING PHYSICAL CAPACITY

The conditions under which the proposed test is to be administered restricted suitable items to:

1. Items requiring a minimum of time, knowledge, and equipment to administer. (Minimum time—two minutes or less for an individual test; minimum knowledge—ability to follow instructions for administration of a test not requiring medical diagnosis; minimum equipment—watch, tape measure, etc.)
2. Items supplementing the medical examination.
3. Items suitable as a premedical screening test, i.e., those not requiring exertions too strenuous for unselected groups, and those measuring general functions related to physical capacity.

4. Items having reasonable objectivity.
5. Items not duplicated in other items.

Three hundred and five items, used in eighty-nine tests, were analyzed. Six items satisfied all criteria. They were as follows:

1. Breathlessness after activity.
2. Physical ability.
3. Pulse rate, vertical.
4. Change in pulse rate from horizontal to vertical position.
5. Pulse rate immediately after exercise.
6. Time for pulse rate to return to normal after exercise.

These items were all used in the test.

There were six additional activities which satisfied all criteria, with the exception that they duplicated each other in that they were all large-muscle movements. These were:

1. Front leaning rest, from standing position (at maximum speed).
2. Hopping one hundred feet.
3. Jump and reach.
4. Jumping, vertical height.
5. Raising body five times in fifteen seconds by placing right foot on a chair eighteen inches high.
6. Running in place for fifteen seconds.

Experiments were made, and the first of these activities, the front leaning rest, from standing position, was found most suitable for the purposes of the test in that four repetitions of this movement afforded not only a measure of large-muscle ability, but also a convenient method of securing the responses measured by the other items in the test. The other five activities were therefore dropped, and the front leaning rest exercise was retained and added to the items previously found to satisfy all criteria. The selection of suitable items was then completed.

It is not necessary to assume that the methods of selection were wholly objective, for the primary purpose was the isolation, for further study, of suitable items. The method was adequate in

that seven such items were obtained. To the extent that the selected items included all those that appeared suitable for examiners not trained in medical diagnosis and limited in time and equipment, the results of this study indicate the possibilities of such examinations.

## Significance of Selected Items

The validity of the test rests primarily upon the validity of the conclusions concerning what constitutes a questionable reaction in the individual items, for all responses are divided into two types: (1) those which indicate normal physical condition; and (2) those which indicate questionable physical condition. Considerable pains have been taken to insure accuracy on this point, and only those reactions not found in individuals known to be in good condition and found in pathological individuals and others not in good condition are considered questionable, and then only when investigators are in agreement that such reactions are indicative of poor condition. These conclusions are based upon numerous studies, involving approximately 4,000 cases. In general, the conclusions reached should be valid. However, because of the minor fluctuations that occur in all individuals, from time to time, in the reactions measured by the several items, it has not been possible to determine with complete objectivity the point where a rate ceases to be normal and abnormality begins, and it is extremely doubtful that such a point exists. The significance of the measures studied, as indicators of questionable condition, has not previously been established. It is hoped that the result of these investigations will help to clarify this issue.

## Building the Items into a Test

The use of the regression equation for weighing and combining the items was considered and rejected. An analysis of the data showed three peculiarities which made this method unsuitable. Further, the selected items did not measure the same attributes of health, but separate and distinct phases of it. It was, therefore,

desirable that the results indicate these phases and not be expressed in a single numerical score. This was accomplished by administering and scoring each item as a separate test. All items, however, were standardized upon the same test exercise.

Numerous advantages and disadvantages accrue when this method is used. These have been previously discussed. The writer holds no special brief for the method used, other than that it is appropriate to the data and the problem, especially in that, through its use, the full diagnostic value of each item is retained —a consideration of major importance in a diagnostic test.

As the unchanged scores of each item are included in the final result, and the selected items are not included in the medical examination, the test may therefore be used to supplement the medical examination.

## Values and Limitations of the Test

The diagnostic value of the test in the detection of cardiac defects was studied by comparing test results with the diagnoses of physicians. Cardiac disorders which limited physical activity were detected; disorders which did not limit function were not detected. These results were compared with the results of the Pulse-Ratio Test and were found to have equal diagnostic value.

The diagnostic value of the test in the detection of non-cardiac defects was also studied by comparing test results with abnormalities disclosed by medical examinations. Abnormalities were found much more frequently in individuals who fail than in others, and few failed cases were found without one or more symptoms of a fatigued, run-down condition. As abnormalities were present in both groups, it cannot be concluded that because an individual passes the test abnormalities are entirely absent. This prevents substitution of the test for the medical examination.

The diagnostic value of the test varied considerably with different abnormalities. The abnormalities most closely associated with failure to pass the test were: poor posture, poor nutrition, poor musculature, flat feet, low hemoglobin, and blood-pressure defects.

The relationship between functional tests of health, or physical

condition, and health as measured by other criteria has been much debated and frequently studied. There is, however, little agreement, for some investigators report high correlations, while others find little or no relationship. The results of our investigations give a clue to one cause of these variations. It is obvious that when the criterion of health consists primarily of items relating to posture, musculature, nutrition, blood pressure, etc., which are closely related with the results of functional tests, the correlation between the criterion and the tests will be high. When the criterion consists of items relating to lungs, chest, reflexes, nose, etc., but not closely related to the results of functional tests, the correlation will be low. Further investigations are necessary to clarify the relationship between functional tests and health. The data of this study indicate that one cause of this invalidity is the practice of defining health in terms of membership in this or that hospital group, and not in terms of specific, verifiable abnormalities.

The reliability of the pulse rate items was studied under three conditions: (1) by immediate retesting by same examiner; (2) over extended periods of time; and (3) when administered by different examiners. Upon immediate retesting, reliability coefficients of .75 to .94 were found. Over extended periods of time, the reliability of the items varied with the variations in physical condition. Individuals who had consistent health status during the experiment had reliable rates. When the physical condition changed during the experiment, the rates changed also, and the reliability was low. Between the scores of different examiners, the correlation was $r = .97$.

Temporary variations in physical condition were allowed for in the scoring of the test by requiring a retest for all cases which exhibited questionable or extra-standard rates. Only those rates which, upon re-examination, were found to be reliable are considered significant.

## Conclusion

The measurement of physical capacity, as defined in this study, that is, active power to accomplish physical work and the ability to

use this power, requires a complete knowledge of the individual's physical condition and ability. The numerous investigations undertaken and herein reported have been related and restricted to those techniques that are suitable for administration under adverse conditions, and it is not to be expected that the results constitute a comprehensive measure of physical capacity. Nevertheless, incomplete and fragmentary as the data are when compared with the many-sided richness of an individual's physical equipment, it is hoped that they carry us beyond previously established facts by contributing a knowledge of:

1. The methods of measuring physical capacity which are suitable for teachers and counselors.
2. The values and limitations of those measures which are suitable for a supplementary-screening test.
3. A convenient method of administering these measures.
4. The values and limitations of the results.

Specifically, the results of this study are as follows:

A test comprising many, if not all, methods of measuring physical capacity that require a minimum of time, knowledge, and equipment to administer was developed.

This test was administered in from two to three minutes as an individual test, and required only a watch as equipment.

Seven important functional aspects of physical capacity were measured, and each result is indicated unchanged in the test score.

The test separated individuals into two primary groups: those who passed and those who failed.

Individuals who pass the test have:

1. Normal vertical pulse rate.
2. Normal postural pulse rate change.
3. Normal pulse rate increase after exercise.
4. Normal pulse rate reaction after exercise.
5. Normal breathlessness after exercise.
6. Normal physical ability.
7. Normal range of motor movement.

These individuals (passed cases) may have abnormalities which do not limit motor function. As a group they have fewer abnormalities than individuals who fail the test.

Individuals who fail the test have one or more of the following reactions:

1. Excessively high or low vertical pulse rate.
2. Exaggerated postural pulse rate change.
3. Excessive pulse rate increase after exercise.
4. Slow pulse rate return to normal after exertion.
5. Poor ability in executing active motor movements.
6. Excessive breathlessness after exertion.
7. Limited range of motor movement.

As a group they (the failed cases) have more abnormalities than individuals who pass the test, and fatigue symptoms are frequently present.

As a cardiac test, the proposed test compares favorably with the Michigan State Test and the Pulse-Ratio Test.

The results of the test are highly reliable.

The test may be used in:

1. Physical education as a preliminary screening test to separate participants in activity programs into two groups: (1) those who are apparently normal and who may be allowed supervised activities pending the medical examination; (2) those who have questionable reactions and should be referred to a physician for diagnosis before participating in activity programs.
2. Health guidance as a supplement to the medical examination to furnish information concerning the functional ability of the subject.
3. Guidance as a screening test to identify individuals who may be limited in their capacity to perform physical work.

Many other studies are necessary to explore fully the possibilities of this test, for its value in the hands of teachers and counselors can be found only by actual trial. There are numerous other approaches to the solution of the problem of identifying the

seemingly unfit which also offer promise. These, too, need investigation.

It is hoped that the results of this study may stimulate teachers and counselors to become more aware of the importance and complexity of physical capacity as a conditioning factor in education, and to study further physical capacity, conscious of the values and limitations of the methods at their disposal.

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# APPENDIX

## TABLE 22

STANDARD DEVIATIONS OF GOOD CONDITION SCORES

| Standard Deviation | Tests | | | | |
|---|---|---|---|---|---|
| | Vertical Pulse Rate | Postural Pulse Rate Change | Increase in Pulse Rate | Time to Return to Normal | Time to Perform Exercise |
| 3. .......... | 109.0 | 19.1 | 64.4 | 174.6 | 13.2 |
| 2.5.......... | 104.5 | 16.6 | 59.3 | 158.9 | 12.5 |
| 2. .......... | 99.9<br>(97.4)* | 14.2<br>(12.6)* | 54.2 | 143.2 | 11.8<br>(11.5)* |
| 1.5.......... | 95.4 | 11.7 | 49.1<br>(46.8)* | 127.5<br>(118.9)* | 11.2 |
| 1. .......... | 90.8 | 9.3 | 44.0 | 111.8 | 10.5 |
| .5.......... | 86.2 | 6.8 | 38.9 | 96.1 | 9.8 |
| 0. .......... | 81.7 | 4.4 | 33.8 | 80.4 | 9.1 |
| −.5.......... | 77.1 | 1.9 | 28.7 | 64.7 | 8.5 |
| −1. .......... | 72.6 | −.5 | 23.6 | 49.0 | 7.8 |
| −1.5.......... | 68.0<br>(66.9)† | −3.0 | 18.5 | 33.2 | 7.1 |
| −2. .......... | 63.4 | −5.4 | 13.4 | 17.5 | 6.4 |
| −2.5.......... | 58.9 | −7.9 | 8.3 | 1.8 | 5.8 |
| −3. .......... | 54.3 | −10.3 | 3.2 | | 5.1 |

* Critical scores—95th percentile.
† Critical scores—5th percentile.

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| JUL 18 [illegible] | | | |
| ~~AUG 28 1959~~ | | | |
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